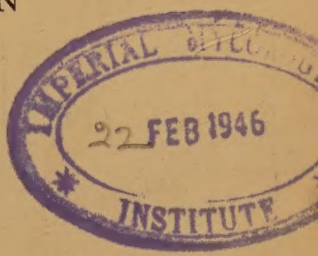
FORESTRY

THE JOURNAL OF THE SOCIETY OF FORESTERS OF GREAT BRITAIN

Edited by H. M. STEVEN

VOLUME XIX

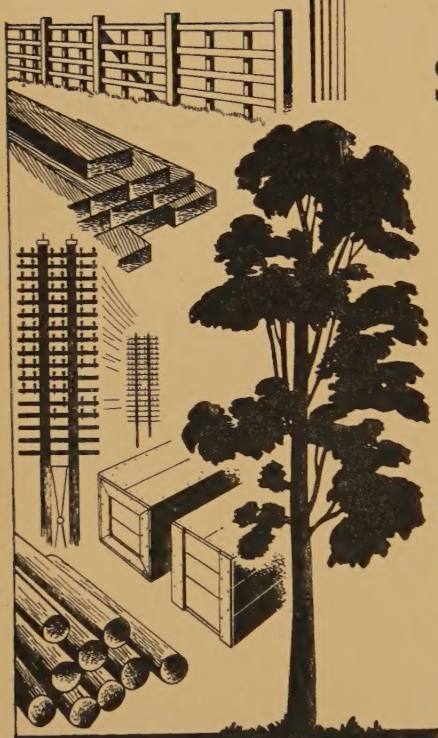


Price
Fifteen Shillings

Published by the
OXFORD UNIVERSITY PRESS
LONDON: GEOFFREY CUMBERLEGE
AMEN HOUSE, E.C. 4
1945

LUMBERMEN
and
SAWMILLERS

with over a century of service



- TELEGRAPH POLES, PIT PROPS, COLLIERY TIMBERS, RAILWAY SLEEPERS, PACKING CASES, BOXWOOD, ESTATE, FARM, & GARDEN FENCING

Estd. 1824

A & G. Paterson
LIMITED

ST. ROLLOX SAWMILLS & BOXWORKS

60-80 Tennant St. Glasgow C.4

TELEPHONE: BELL 3236 (3 lines)

Permanent Sawmills at Banchory & Aberdeen
FOREST SAWMILLS THROUGHOUT THE COUNTRY

FORESTRY

THE JOURNAL OF THE SOCIETY OF FORESTERS OF GREAT BRITAIN

Edited by H. M. STEVEN

VOLUME XIX

Published by the
OXFORD UNIVERSITY PRESS
LONDON : GEOFFREY CUMBERLEGE
AMEN HOUSE, E.C. 4
1945

FORESTRY

CONTENTS OF VOLUME XIX

A Note on Corsican Pine. By SIR ROY LISTER ROBINSON 1

A Discussion of Causes of dying-back of Corsican Pine, with special reference to Frost Injury. By W. R. DAY 4

Weeding and Cleaning. By W. L. TAYLOR 27

Neglect of Natural Regeneration. By RAY BOURNE 33

Preliminary Observations on the Influence of Site Conditions on Natural Regeneration, with special reference to Dunecht Estate, Aberdeenshire (with Plates I and II). By W. M. MCNEILL 41

Establishment of Oak Plantations in East Anglia. By G. D. ROUSE . . 56

Conversion of Birch Scrub areas to Coniferous Woodland in the North of Scotland. By ANDREW WATT 62

The Lon Mor: Twenty Years' Research into Wasteland Peat Afforestation in Scotland (with Plates III and IV). By J. ALAN B. MACDONALD 67

Cultivation of Chestnut Coppice and its Utilization in War and Peace. By W. ANGUS MUIR 74

Charcoal Production. By L. G. T. KENYON 86

The Utilization of Alder Buckthorn. By F. G. O. PEARSON 95

The Preference shown by Birds for Different Species of Trees in Plantations. By J. M. D. MACKENZIE 97

Experiences in Harvesting Timber and their Application to Silviculture and Management (with Plates V and VI). By B. P. URQUHART . . 113

Society's and other News 128

REVIEWS

Co-operation in Forestry (I. KISSIN) and Forestry Credit (I. KISSIN). By HENRY HAMILTON 130

Forestry on Private Lands in the United States (C. F. KORSTIAN). By JAMES MACDONALD 131

Trees and Toadstools (M. C. RAYNER) and Taxonomic-Ecologic Studies of the Boletaceae in Northern Idaho and Adjacent Washington (A. W. SLIPP and W. H. SNELL). By H. M. STEVEN 133

NOTICES

Behold Our Green Mansions (RICHARD H. D. BOERKER). Erosion in the Punjab, Its Causes and Cure (SIR HAROLD GLOVER) 134

Mining Timber (S. E. WILSON) 135

Swelling Stresses in Gels (W. W. BARKLAS) 135

Forests and Forestry in Great Britain (W. L. TAYLOR) 136

PRINTED IN GREAT BRITAIN

SOCIETY OF FORESTERS OF GREAT BRITAIN

THIS SOCIETY was formed in 1925 and adopted its first Constitution at Oxford in 1926. The object of the Society is to advance and spread in Great Britain the knowledge of technical forestry in all its aspects.

The Society consists of Professional and Ordinary Members. Professional membership is divided into two orders:

FELLOWS, being holders of a degree or diploma in forestry, and subjects of the British Crown, but not necessarily resident in Great Britain; and

ASSOCIATES, being subjects of the British Crown resident in Great Britain, whole-time foresters, and not eligible for Fellowship. They pay a less subscription than Fellows but have almost equal privileges.

Ordinary membership is open to persons not eligible for either of the above.

Office-bearers and Councillors are nominated by Professional Members, and in the event of competition for any office a postal ballot of the whole Professional membership is held. The following were elected to serve in 1945:

President: W. H. GUILLEBAUD, B.A., Director of Research, Forestry Commission.

Vice-President: OWEN J. SANGAR, M.C., Director for England, Forestry Commission.

Editor of Journal: PROFESSOR H. M. STEVEN, M.A., PH.D., 75 Fountainhall Road, Aberdeen.

Business Editor: J. ALAN B. MACDONALD, 25 Drumsheugh Gardens, Edinburgh, 3.

Secretary and Treasurer: R. ANGUS GALLOWAY, M.C., B.SC., Solicitor, 8 Rutland Square, Edinburgh, 1. Tel. No., Edinburgh 23842.

Auditor: D. L. FERGUSON, 25 Drumsheugh Gardens, Edinburgh, 3.

Councillors: WHEATLEY A. ROBERTSON, F.R.G.S. (Immediate Past President).

A. H. GOSLING, B.SC.

T. R. PEACE, M.A.

C. A. CONNELL, M.A.

E. V. LAING, M.A., D.SC.

C. H. THOMPSON, M.A., DIP. FOR.

W. L. TAYLOR, C.B.E., F.S.I.

THE SOCIETY AND ITS JOURNAL

THE IMPORTANCE OF FORESTRY is being realized more and more in Great Britain. The number of foresters is increasing steadily, and a forestry profession is gradually being built up. It is intended that this Society should be representative of the profession. Those who are not engaged in the practice of forestry or the allied sciences are cordially invited to join the Society as Ordinary Members.

SUBSCRIPTIONS are:

Fellows and Ordinary Members: £1. 1*s*. 0*d*. annually or £10. 10*s*. 0*d*. for Life.

Associates: 10*s*. 6*d*. annually.

THE SOCIETY'S JOURNAL, called *Forestry*, is published twice a year, in June and December. It provides a means for the publication of the results of practice and research both in the growing of timber and in its utilization, including such basic sciences as forest physiology and ecology, forest soils, wood structure, and timber physics, and allied sciences such as forest entomology and forest mycology.

CONTRIBUTIONS may be accepted from members and others resident either in Great Britain or abroad. They should be sent to the editor, Professor H. M. Steven, 75 Fountainhall Road, Aberdeen. No article should be submitted which is being offered to any other journal for prior or simultaneous publication. Articles should be typewritten, and must be in a final form suitable for publication. References to literature should be collected at the end of the paper, and arranged alphabetically according to author's name, and numbered. In the text each reference should be indicated by its number enclosed in brackets. Each article should conclude with a summary. It should give the methods, extent of material, observations, and results, but should be brief and not exceed 3 per cent. of the original. It is understood that the author waives any copyright or translation rights in such summaries and that their reproduction in other publications will be permitted, subject to the source being duly acknowledged. Twenty reprints of the article will be sent free to each contributor and a reasonable number may be purchased by the contributor if ordered when the proofs are returned. The Society as a body takes no responsibility for the views expressed by contributors.

Forestry is sent free to members of the Society; others may register as subscribers by application to the Secretary, R. Angus Galloway, 8 Rutland Square, Edinburgh, 1.

SOCIETY'S MEDAL. The Council has resolved that the Society award a Medal from time to time to any individuals who may have rendered eminent services.

A NOTE ON CORSICAN PINE[1]

By SIR ROY LISTER ROBINSON

PINUS laricio var. *Corsicana* grows in its native habitat at 3,000 to nearly 5,000 feet above sea-level. Below is a Maritime pine belt and above beech, with locally a narrow upper fringe of Common Silver fir. One would expect on general grounds that this natural vertical distribution in the Mediterranean would apply from south to north in Britain and there seems some reason to think that such is the case. The soil of the Corsican mountains is derived from granite, and so is very different from that of the limestone formation on which *P. laricio* var. *Austriaca* grows in the territory at the head of the Adriatic Sea. That difference is important to note because there is a natural tendency to assume that the silvicultural characteristics of the two trees are the same.

Corsican pine grows very well on the sandy heaths of southern and eastern Britain and on sand-dunes as far north as Culbin, on the Moray Firth. It is in fact the best tree on dunes which are recently fixed, but may be a failure on the tightly packed and damp flats between the dunes. Where conditions are otherwise favourable it does well on loams and even heavy clays (Isle of Wight). On the other hand, Corsican pine is at best a short-lived tree on limestone and chalk soils, and there are definite limitations to the elevations to which it may safely be taken in hilly country. In the industrial midlands it is the best conifer on smoky sites. Austrian pine is equally unreliable for hill planting but, as already noted, seems at home on calcareous soils.

Corsican pine is a most valuable tree when planted in the right environment. It grows much quicker than Scots pine and is less subject to shoot damage by pine beetles and pine tortrix, which can become serious pests on Scots pine. *Pissodes notatus*, however, may be a serious nuisance on Corsican pine, particularly when associated with Maritime pine. Corsican is perhaps more prone than Scots pine to honey fungus on old hardwood sites.

When grown on economical rotations the timber is practically all sapwood and very absorbent of creosote. It is not as good as Scots but is better than was commonly thought. Further, for plywood it is one of the best of the common conifers, and there should be a good future for well-grown trees. Pruning will be necessary, but the cost should be covered many times over. Timber merchants who before the war were somewhat scornful of the Forestry Commission plantations in East Anglia have since admitted that they under-estimated the value of the tree.

Rate of Growth. Scots and Corsican pines have both been planted on a very large scale in East Anglia over the last 25 years, often under identical conditions. Thinning has been proceeding actively, and a generalized picture of the

[1] This 'Note' forms an introduction to the communication on 'The Dying-back of Corsican Pine' which follows.

comparative rates of growth of the two species is given in the table below. The data have been provided by Mr. C. A. Connell.

The table brings out clearly the faster production of Corsican pines. With the best crops there will have been three thinnings between the 16th and 25th years, yielding 1,060 cu. ft. and leaving 2,070 cu. ft. standing in the 25th year. With Scots pine there will have been only two thinnings in that period, yielding 410 cu. ft. and a standing crop of 1,530 cu. ft. The mean annual increment for the first 25 years is: Corsican 125 cu. ft., Scots 78 cu. ft.

East Anglian Pine Plantations. Volumes per acre Q.G.U.B.

	Corsican pine			*Scots pine*		
Age	*Thinnings (cu. ft.)*	*Main crop*	*Total yield*	*Thinnings (cu. ft.)*	*Main crop*	*Total yield*
16		820	1,080		675	675
17	1st. 260	980	1,240		760	760
18		1,165	1,425		860	860
19		1,375	1,635		835	970
20		1,250	1,860	1st. 135	960	1,095
21	2nd. 350	1,450	2,060		1,105	1,240
22		1,680	2,290		1,270	1,405
23		1,950	2,560		1,185	1,595
24	3rd. 450	1,800	2,860	2nd. 275	1,350	1,760
25		2,070	3,130		1,530	1,940

Corsican pine continues to maintain this early lead on volume production. A good example is found in New Forest Sample Plots 102 and 103. At 79 years of age the Corsican plot contained 5,760 cu. ft. and the Scots 3,890 cu. ft. A striking example of Corsican production is Sample Plot 83 in Bere Forest; at 57 years the standing volume was 7,280 cu. ft. and the mean annual production, including thinnings, 158 cu. ft. Unfortunately there is no comparable Scots pine plot.

Personal Experiences with Corsican Pine. In common with others I started off 30 years or so ago with the assumption that because Austrian pine was at home on calcareous soils Corsican pine would do well. It gradually became apparent that this was incorrect. A flourishing plantation of about 15 years on mountain limestone in High Meadow Woods suddenly began to die and was soon a wreck. A young plantation on the Oolite at Cirencester followed suit, and from time to time I subsequently noted the same phenomena on the chalk of southern England. There were occasional indications, however, that by heavy thinning the dying off could be arrested or possibly avoided by mixture with hardwoods. It may be noted here that Scots pine is also short-lived in pure plantations on chalk, but that in a matrix of beech may attain to quite large dimensions. These two pines in fact persist long enough to 'nurse' up a crop of beech.

As regards the behaviour of Corsican pine in hill country, about 1912 I made measurements of a good crop at Kerry in mid-Wales; it was growing on good soil on a steep and well-sheltered site, the standing volume was 6,300 cu. ft. at 40

years at an elevation of 900 feet. A year or two later preparations had to be made at Lake Vyrnwy, also in mid-Wales, for a 4,000-acre afforestation programme on plantable land running up to 1,400 or 1,500 feet. There were then (and still are) excellent Corsican pine growing just above the lake level (at, say, 1,000 feet) and a flourishing young plantation 12–15 feet high some 200–300 feet higher up the slope. On the strength of this evidence Corsican belts were planted at even higher elevations. Very soon trees in the young plantation just referred to began to die just as they did in the High Meadow and later the belts suffered the same fate. (Incidentally an excellent example of the dangers of extrapolation.) The same thing began to happen in Corsican pine belts planted at relatively high elevations on Forestry Commission properties at Thornthwaite in Cumberland and elsewhere. On such evidence I came gradually to the conclusion that there were fairly sharp limits to the successful use of the species in hill country, and Divisional officers were warned from time to time of the risks. The most plausible explanation of failures seemed to be that, as on calcareous soil, the tree was being taken out of its natural environment. On chalk and limestone the soil was unsuitable, and in the high hill country the climate was at fault. In the mountains of Corsica the winters are cold with several feet of snow but the summers are sunny and hot. It seemed reasonable to suppose that in our comparatively wet, cold, and sunless hill climates a point might be reached where new shoots would not ripen in the autumn. Frost damage, fungus diseases, and insects might then be expected.

A DISCUSSION OF CAUSES OF DYING-BACK OF CORSICAN PINE, WITH SPECIAL REFERENCE TO FROST INJURY

By W. R. DAY

(*Department of Forestry, University of Oxford*)

INTRODUCTION

IN one form or another an infectious die-back of the crown of two-needled pines has been recognized for more than 50 years in western Europe and more recently in North America (1, 4, 5, 8, 11, 12, 16, 18, 19). All ages of tree from seedlings upwards have been reported as being subject to the disease, but in this country attacks seem usually to have been observed on young plantations of not more than 20 years old (22, 21, 15). Some authors (19, 4) have considered that unfavourable weather conditions were necessary in order that pines might become susceptible to infection, while, in one case, previous infection of the root system by *Armillaria mellea* or *Fomes annosus* was believed to have been the predisposing factor (18). This disease has been associated in Europe with the fungus *Brunchorstia destruens* Eriks. and its occurrence in Britain has been referred to upon several occasions (22, 21, 19) and has been associated particularly with Corsican and Austrian pines (*Pinus laricio* var. *Corsicana* and *P. laricio* var. *Austriaca*). *B. destruens* was believed for many years to be the pycnidial form of *Cenangium abietis* (Pers.) Dub., which may occur with it on dying pines. Lagerberg (12), however, claimed that it belonged to *Crumenula abietina* Lag., a species not dissimilar to *C. abietis* in outward appearance, and this seems to have been confirmed (22, 3, 16).

The development of stem and branch canker is also of not uncommon occurrence on Corsican and other pines. The affected trees may or may not be suffering from die-back and their age may be anything up to at least 50 years. *Dasyscypha pini* (Brunch.) Hahn and Ayers (*D. Fuscosanguinea* Rehm) has been associated with this form of disease in U.S.A. According to Boyce (4) such canker formation is mostly restricted to high elevations or to poor sites. It may also be found in such situations in Britain, but may occur quite commonly elsewhere. It is rarely serious, in this country, in its effect on the value of the tree: *D. calyciformis* (Willd.) Rehm has been observed in association with it.

The tendency to associate these diseases of the bark of pine with unfavourable climatic or edaphic conditions, as well as with a parasite as the actual cause of die-back, is interesting because sometimes a non-parasitic factor is plainly the cause of the disease. Steven (20) reported severe damage to Corsican pine by September frosts in Nottinghamshire and Lincolnshire, and by August frosts in Morayshire, both in 1932. Corsican and Scots pine sent to Oxford from East Anglia in 1933 showed obvious signs of die-back: both species proved to have been severely

cut back by frost. This type of injury has never been severe on the East Anglian heaths which have been afforested with pine since 1920, but the occurrence of frost rings is widespread in the inner annual rings of young pine growing there, showing how near is often their escape from serious injury by frost. About the same time, 1933, T. R. Peace also found Corsican pine killed by frost in a small frost hollow in Delamere Forest in Cheshire; several other species, including Sitka spruce, had been severely injured also. Further cases of severe frost injury were reported after the severe May frost in 1935 (7 (*b*), pp. 60 and 61).

It is of course well known that the killed parts of frost-injured trees are always subsequently colonized by fungi, and an instance was discovered in New Zealand (2) in which infection of living tissue of *Pinus radiata* by *Phomopsis strobi* was possible only after frost injury had occurred.

Langner (13) claims that the importance of *Dasyscypha willkommii* (Hart.) Rehm, the larch-canker fungus, in the development of canker and die-back of European larch is that it so affects the live tissue which surrounds frost wounds that the susceptibility to frost injury is raised. Leach (14) also describes interesting relationships between frost, insects, and fungi in connexion with winter injury to fruit-trees in U.S.A. There also frost is of primary importance as a killing agent, while insect and fungi help to maintain and stimulate the development of disease. There is thus ample evidence to show that in any case of canker or die-back of apparently infectious origin, careful investigation is needed to make certain whether or not other factors, whether biotic or physical, are of importance in the development of the disease.

In special cases other factors than either frost or fungus may be concerned in die-back of pines. For example, in Pembrey Forest on the coast of south Wales there is clear evidence of frost injury to Corsican pine, but the main cause of die-back is exposure to sea-wind. A more important case is the dying-back of this species on calcareous soils. This seems clearly to be associated with the lime-saturated nature of the soil, and to be a type of lime-induced nutrient deficiency. It has been observed in several places on the chalk hills in the southern part of England. The most extensive occurrence noted was in a wood, now felled, near to Hungerford in Berkshire. Here European and Japanese larch showed marked signs of lime-induced iron deficiency, to which both species are highly susceptible. Scots and Corsican pines had also produced chlorotic shoots, and were presumably suffering from the same deficiency. An examination of samples of the root system of the pines made by Dr. Levisohn showed that the Corsican pine roots had a very deficient mycorrhizal equipment, and it seemed probable that this abnormality in the absorbing roots was at least one factor in producing the diseased condition of the trees.

Sometimes, however, Corsican pine seems to be resistant to highly calcareous soil conditions. Thus in Allerston Forest in the East Riding of Yorkshire Scots pine has been suffering for some time from what has been imputed to be a lime-induced manganese deficiency, although the actual death of the trees seems to be brought about by severe defoliation owing to pruning resulting from infestation by *Myelophilus piniperda* L., the pine-shoot beetle. Corsican pine growing near

by on the same type of soil have proved markedly resistant. Inconsistencies such as that which appears here with regard to the growth of Corsican pine on calcareous soils can only be resolved by means of more intensive investigations.

It is plain from the above that more than one factor may have to be taken into account when considering die-back of Corsican pine. In view of the fact that fungi will, in any case, colonize dying or dead tissues, and that this colonization is restricted to a relatively small group of species, the members of which may or may not have some parasitic powers, it is particularly necessary to determine as carefully as possible the sequence of events which characterize any actual appearance of die-back. This matter is made more complicated, as regards fungus infection, by the occurrence of defoliation or severe needle scorching, either together with or independently of dying back. Four species of fungi have been observed on affected needles. They are: *Hypodermella sulcigena* (Link) v. Tub., *Diplodea pinea* Kick (=*Sphaeropsis ellisii* Sacc.), *Brunchorstia destruens* Eriks., and *Sclerophoma pithyophila* v. Hohn. Most commonly the affected needles are killed for about three-quarters or four-fifths of their length, a small basal portion remaining alive. There is no evidence that this injury to needles ever causes the affected trees to die back, although there seems to be no reason why it should not if severe enough. On the other hand, there is no satisfactory evidence as to the character of these fungi in relation to their host. When any one of four different species occurs in connexion with injury having the same physical appearance it may be suspected that some other factor may play an important role in the development of the disease.

The resolution of all the complexities of this problem of the causes of the dying-back and canker of the crown of Corsican pine is not to be expected without much further investigation. In this paper experience is summarized which has been gained mainly during the last three years in plantations visited and from specimens sent in from widely separated forests distributed throughout the west and north of England and Wales. It will be seen that the fundamentally important factor responsible for the death of stems and branches is diagnosed as frost injury. Only a summary statement of the main features of this are given here; the detailed discussion of its symptoms, and especially of the anatomical details upon which its final diagnosis often depends, is reserved for a later paper. Also, it has not been possible in this work to follow in detail the sequence of infection and infestation, by fungus and insect, which is the natural result of frost injury. The full ecological development following such injury thus has still to be worked out; economically, however, this is of secondary interest; the determination of the primary killing factor is the important matter.

THE DIFFERENT ASPECTS OF FROST INJURY IN CORSICAN PINE

There has been hitherto no attempt to describe or to provide experimental proof of the various aspects of frost injury in Corsican pine. Diagnosis thus depends on what is known to be generally true of the character of frost injury in conifers. A detailed and illustrated description, based upon experimental work, as well as upon observation of material collected in the field, is given by Day and

Peace (7 (*a*)). They used Scots pine to a slight extent in their experimental work, but Corsican pine not at all. Nevertheless the reaction of various species of tree to frost injury is sufficiently similar to enable the characteristics given by them to be of general service in diagnosis. The greatest deficiency in information is with regard to frost injury to pine needles. Day and Peace showed that young Scots pine can be defoliated by exposure to suitable low temperatures, even in the middle of winter, but there is no evidence with regard to the occurrence of the partial killing of foliage which is typical of frost injury on conifers belonging to other genera and almost certainly occurs on pines. For this reason one cannot speak with any authority with regard to the needle diseases of pines with which, as indicated above, various fungi are associated and which frequently involve the death of only a part of affected needles. The position with regard to injury to stems is, however, reasonably clear and the characteristics of frost injury can be recognized with comparative ease, especially if abnormalities in the structure of the tissues of bark and wood are taken into account.

A. *The characteristic external signs of frost injury to pine are summarized below:*

(Not all of these need appear on any one tree affected and such as do appear may not, in themselves, be sufficient to warrant the diagnosis of frost injury without an examination of the anatomy of the specimen.)

1. The terminal buds and the adjacent stem are killed and the needles which surround them begin to die, turning brown from the base upwards. This injury occurs before flushing takes place: injury to the newly developing shoots by late frost is less usual but may occur extensively in suitable seasons and situations.

2. Larger or smaller areas of dead tissue appear in the bark of young and normally still smooth-surfaced stems. These need not extend through to the cambium and may only be detected by cutting the bark, if an examination is made fairly soon after injury has occurred.

3. Rough fissured bark appears, especially at the base of the stem on young trees, which should still have smooth-barked stems. This is really an advanced stage of 2.

4. Cankers may appear on affected stems or branches. They may be numerous and, although they may occur on any part of the stem or branch system, they often tend to be most numerous around the branch nodes.

5. Resin flow, which may be copious, occurs on stems the bark of which has been injured. No insect tunnels or frass is seen at first, although they may be observed later.

6. The crown dies back if injury has been sufficiently severe. This die-back often begins around the lower part of the crown of trees in plantations which have not yet formed canopy, but the top of the tree may be severely affected; this is especially so in older stands which are in close canopy.

7. Severely affected trees often die. They become colonized by various fungi and infested with insects, especially the *Pissodes* weevils. The occurrence of frost injury may be less obvious than this infection or infestation of dead or dying branches.

8. It is usual for trees, which have died back partly, to produce adventitious shoots. Normally these develop from the dwarf shoots of the pine. Infestation by *Myelophilus piniperda* or by pine-shoot moths also induces this type of development, but the hollowed shoots which are typical of injury by these insects are absent with frost injury.

9. Weevil or other bark-beetle attack is a common accompaniment of frost injury. It is never present when the injury has occurred only recently, but on stems of sufficient size it is often abundant subsequently. It is characteristic of this type of weevil attack that there is an absence of resin flow from the points at which the insects have entered the stem.

10. Quite young stems tend to escape serious injury, although this may and sometimes does occur in them. In many places serious injury first occurs when the plantation has entered, or is about to enter, the thicket stage (Table I). It may continue at least until the pole stage is reached and the trees are 30 feet or more in height.

11. If the relationship between local climates and the topography of the locality in which the pines are growing is sufficiently understood, it will usually be plain that the situations in which the disease is worst are those in which low temperatures are likely to be most severe (Table I).

B. *The characteristic internal signs of frost injury are as follows:*

1. The medulla, especially in 1- or 2-year-old shoots, is rent and shows collapsed tissue especially in its outer part near the protoxylems. Not infrequently, when the injury is severe but one-sided, an internal cambium is formed which produces a cork layer to cut off the dead tissues from the live. Normal bark and wood may be produced by this cambium, within the dead medulla region.

2. Rents also commonly appear in the meristem and phloem and, if present, in any as yet incompletely developed woody tissue.

3. The outer part of the cortex is often killed (see A.3, above). No fungus mycelium, or signs of insect infestation, are seen in this if the examination is made soon enough; but they may otherwise be expected. Slighter forms of frost injury take the form of scattered groups of brown cells in the otherwise living cortex.

4. Frost rings may sometimes be seen in the wood, and the death of the meristem may obviously be connected with them.

5. Abnormal woody tissue frequently occurs which takes the form of a zone consisting chiefly of narrow coffin-shaped cells: this occupies the position which marks the end of one annual ring and the beginning of another. These zones are, in reality, frost rings, although they differ markedly in appearance from such a ring as it usually develops after the formation of wood has begun.

6. A close examination will show that in many cases the injury has been caused by autumn frosts, and observation will demonstrate that this was possible because it is characteristic of Corsican pine to continue the formation of wood until after these frosts have begun. Injury by spring frosts also occurs but seems to be much less common.

As noted in the case of the external signs of injury, all the characteristics noted

above may not appear in any one specimen. If a sufficient number of specimens are examined, however, the presence or absence of frost injury can usually be determined satisfactorily.

C. *Injury to needles among pines affected by frost.*

Frost damage to needles of evergreen conifers is most commonly seen when a late frost has injured or killed newly developing shoots. Much of the frost injury to Corsican pine stems takes place after all the needles are mature and presumably frost resistant. Observation in the field certainly shows that severe damage to stems can occur and leave needles uninjured. Not infrequently, however, the needles of pines having frost-injured stems show severe damage of the type mentioned above, i.e. many of the needles are dead for three-quarters or more of their length, only their bases remaining alive. This type of injury is usually most severe over those parts of the crown where the branch system has suffered most damage. The suggestion, and at present it can be no more, is that it is one aspect of frost injury, at least in some cases. Proof, however, is still needed.

D. *Confusing symptoms.*

Other diseases can, of course, occur concurrently with frost injury, but it is believed that, if the indications given above are searched for carefully, there will be few failures in diagnosis. Instances of *Pissodes* infestation can occur, for example, in which it is probable that frost injury, although present, is a minor and not a major cause of disease. In such cases some other factor, for example a root infection, or an inadequate soil-water supply during dry periods, has to be looked for as that which has made the tree susceptible to weevil infestation. The pathology of *Brunchorstia* infections has never been adequately worked out, but it is practically certain that, in some cases at least, infection by it has followed upon frost injury, and is, in reality, of secondary importance. Special care is needed, therefore, in searching for symptoms of frost injury in cases where infection by this fungus occurs. It will be noted that if the signs of frost injury given above are compared with the symptoms shown by pines affected by *B. destruens*, as described by Waldie (22) or Lagerberg (12), the two agree very closely. The distinction which Waldie gives between fungus infection and frost injury, namely that in the former there is no clear-cut line between live and dead tissue while in the latter there is such, need not hold good. This will be plain to those who have experience of the complicated pattern of injury and die-back which may follow frost injury and of the consequences of infection of dying stems by weak parasites.

IMPORTANCE OF GROWTH PERIOD IN RELATION TO FROST INJURY

It has been pointed out on previous occasions (6 (*a*) and 7 (*a*)), in connexion with frost injury to other species of conifer, that one of the deciding factors in determining its severity is the relative coincidence between the period of growth of the species of tree concerned and the period of the year, in the habitat under examination, which is usually free from frosts of sufficient severity to cause injury. Thus

one of the reasons why European larch is so commonly subject to frost injury is that its growing-season in this country begins in the late winter (March), and continues until the early autumn (end of September) (6, 7 (*a*)). Japanese larch is similarly affected, though usually to a less serious extent. Early flushing Norway spruce similarly suffers more severely from injury by late frosts than does the late flushing type, because it begins growth earlier in the spring and so has to endure a longer period when spring frosts occur (7 (*a*)).

The evidence collected so far, with regard to Corsican pine, indicates that early (or autumn) frost is that which usually causes injury (20), although damage by spring frost can occur and evidence of it is to be seen not infrequently, as for example, this year (1945) at Slaley Forest, when a severe late frost followed after a warm period which induced an early commencement of growth. Similar observations were made in other places in 1935 (7 (*a*)). Corsican pine is, however, a relatively late flushing tree and its growth period does not usually begin until the worst spring frosts are over. It is also a species which completes its annual shoot growth fairly quickly, e.g. by the end of July according to Hiley and Cunliffe (10), so that apparently it should be free from injury by early frost. However, specimens received in mid-October 1944, from Haldon Forest near Exeter and Llantrissant Forest near Cardiff, showed that the cambium was still actively producing new wood and so likely to be in a frost-sensitive condition. Actual instances of a frost-rent cambium were found in the Llantrissant material. Specimens received from Rheola Forest (Glamorganshire) during the next month, November, showed quite plainly that the cambium had then gone into the normal winter condition. It would appear, therefore, to be quite plain that Corsican pine tends to have too long a period of growth for it to be safe from damage by frost in many parts of this country and here is to be found the fundamental cause of its susceptibility to injury. More observations are needed before any complete statement can be made with regard to the growth period of this species. It is possible, for example, that the relatively hotter summers experienced in the centre and south-east, as compared with the rest of Britain, tend to cause ripening of wood and earlier cessation of growth and that this is the reason for the comparative freedom from die-back in these regions.

TOPOGRAPHICAL POSITION AND SUSCEPTIBILITY TO FROST INJURY

It has been shown many times, and is a matter of common experience among foresters, that the degree of severity of frost injury tends to be correlated with topographical position. The reason for this is that certain positions are subject to greater extremes of low temperature than others. The factors governing this are discussed by Geiger (9) and by Day and Peace (7 (*b*)). It is to be expected, therefore, that frost injury to Corsican pine is similarly associated. Some data with regard to this are set out in Table I. These data refer to places where frost injury has occurred. They give, therefore, an incomplete picture of the relationship between the occurrence of injury and topographical position; for in order to obtain unbiased information there should be an impartial sampling of all types of situation and of healthy as well as diseased plantations. So far as they go, how-

ever, they support past experience (20). Thus severe or moderately severe injury occurred on plateaux or at a plateau edge (Allerston, Fewston, Llantrissant, Rheola, Slaley). A mid-slope may escape or nearly escape injury where nearby upper slopes or plateaux edges have suffered severely (Fewston, Rheola). Folds in a lower slope (Derwent valley), or the bottom of a small valley (Delamere, Fewston), may suffer severely. Low elevation in itself need not ensure immunity from injury: Thus scattered examples of frost-injured Corsican pines have been found among the sand-dunes at Pembrey on the coast of south Wales.

These observations are exactly what is to be expected as to the location of a disease caused by frost injury. They support all the evidence so far obtained as to its normal distribution in relation to topography. Much further observation would be needed before it could be said, in any particular district, what are likely to be the zones in which injury will probably be insignificant, and what are those in which planting involves an appreciable risk. However, it seems safe to say that, on the whole, situations in the more lowland districts may be expected to be much more free from injury than those in the more upland. Thus the majority of the sites mentioned in Table I belong to upland regions; it is to be expected that a sampling of Corsican pine plantations in the lowland parts of the country would reveal a relatively light incidence of disease. This, however, is a matter which must be determined by future observation, and it is already apparent that in lowland regions where severe frost areas occur (e.g. Delamere Forest and Sherwood Forest) disease may be locally serious.

CORSICAN PINE DISEASE IN PARTICULAR LOCALITIES

1. *Slaley Forest, Northumberland*

In a few instances more detailed information has been obtained, with regard to the condition of the crop and the development of disease than is possible during a short reconnaissance. Slaley Forest was one of the first of those in which this had been done.

This is a high-lying forest much of which, including the affected plantations, occurs at elevations of between 1,000 and 1,100 feet above sea-level. Topographically it is essentially a plateau forest. The affected area is in an undulation of the plateau on a gentle slope which runs down to the road bounding the eastern side of the forest. In order to obtain a sample of this area within a short time, a transect was run, beginning in a seriously affected part near the roadside and proceeding in a direction approximately due west and at right angles to the slope, until its top and the locally highest point of the plateau was reached. The length of the transect was 950 feet, and observations were made at ten points along it. The characteristics of the crop at each observation point were sampled by measuring, within a radius of 20 feet around, the total height of each tree and the height increment made over the last 3 years. The severity of disease was assessed for each tree and the height up from the ground to which the crown was affected; note was also made of the distribution, according to point of compass, of disease on the crown of each tree. A soil pit was dug at each point and suitable records made as to profile characteristics. In addition, soil samples were taken at

four points along the transect. Two main types of diseases were observed, namely the die-back of stems and branches with which this paper is principally concerned, and the, usually partial, die-back of needles to which reference has also been made.

The silvicultural data are summarized in Tables II and III. The crop consisted of about equal proportions of two types of Corsican pines irregularly mixed. The taller and better-grown type is that which is usually planted in this country and which is native to the island of Corsica. The other type grows more slowly, is of stiffer habit, and has stiffer and more sharply pointed needles. It is often referred to by the name 'Ursuline' and is so called here, but its actual geographical origin appears to be unknown. Table III shows that this type has made consistently slower growth, the rate usually being about two-thirds that of the normal type. The exception to this is at the 950-foot point on the transect, where the current increment between the two types is not very dissimilar.

The relative variation of height within the crop, as measured by the coefficient of variance (Table II), is different for the two types of pine. The normal type is most variable in height growth within the first 300 feet of the transect; this is correlated, at least in part, with the more severe occurrence of disease in this section (Table V). The Ursuline type, on the other hand, varies most greatly in the central part of the transect, around 400 and 500 feet. This is in the centre of the slope from the roadside to the top of the slight hill and crosses a region in which the lower part of the rooting profile consists of fissured freely draining gritstone and where, probably, the shallower soil depths most commonly occur (Table II). The variation shown within the Ursuline type probably reflects, more truly than does that shown within the normal type, one aspect of the effect upon growth of purely edaphic factors in the area crossed by the transect. It will be seen from Tables V and VI that this type was the less affected by disease at the time of inspection, and, therefore, would have made more consistently normal growth throughout the region covered by the transect. It will be noted also, from Table III, that although the Ursuline type varies comparatively little in total height throughout most of the transect, the height growth of the normal type is smallest and the depth of free-rooting material least, in the region in which the Ursuline type shows the greater relative variations in height growth, as measured by the coefficient of variance. By depth of free-rooting material is meant that depth of soil in which Corsican pine rooted with little or no restriction.

Some indication of the height of dominant trees within the crop is given by the height class within which the 90 percentile falls (Table III). The 90 percentile is that height below which 90 per cent. of trees in the sample occurs. Trees of the normal type plainly form the dominants of the crop, but the 90 percentile is given for both types in order that a comparison may be made between them. This comparison is valid because no over-shadowing of the one type by the other had occurred to any appreciable extent at the time of measurement. The soil data (Table II) show that the first four and the last observation points occur in regions in which the subsoil is usually clay and the subsoil drainage impeded. It is within these parts that the greater dominant heights occur; it is here also

that the greater depths of free-rooting material are also to be found. The number of samples is, however, too small for any clear relationship between this depth and height growth to be demonstrated.

The figures for the height increment made over the three growing-seasons previous to the time of measurement (March 1944) show that the Ursuline type was growing only about two-thirds as fast as the normal type. The indications are plainly that it is a very inferior race from the point of view of rate of growth, at least in situations such as this. There is very little variation between the different positions, although it may be noted that the sample with the poorest mean height has also the poorest rate of increment, while that with the greatest mean height shows the greatest rate of increment with both types of pine. On the whole the figures suggest that over the main part of the transect, where the soil is podsolic in type, the present rate of growth is comparatively even and that differences in height growth will tend to even out.

Table IV gives the result of a series of 'Morgan' tests (17) made by Mr. C. G. T. Morison, Reader in Soil Science, Oxford University, on the samples of soil collected. The results show that, as judged in this manner, the soil in this area has a very low nutrient status. Some of the substances tested for are present in such small amounts that the occurrence of deficiency disease would not be surprising. A certain amount of chlorosis of the needles of the Ursuline type commonly occurs, and it is possible that this is an indication of deficiency. The marked tendency for nutrients to occur to a greater extent in the surface soil (the A1 horizon) in Table IV, than lower down in the profile, is an indication of the importance of the upper layers in nutrient absorption, in poor soils such as those here sampled. It is to be noted that the degraded brown earth does not differ in general character as regards nutrient status from the podsols, although the manner of root distribution within it was quite different. Evidently the physical rather than the chemical character of this soil provided the determining characteristics as regards intensity of root development.

These data seem to indicate plainly that variations in mean height growth along the transect have no connection with differences in nutrient status per unit volume of soil, although a more accurate examination would be needed to prove this. The rate of growth of the crop is not unsatisfactory considering the poverty and shallowness of the soil in most places. The relative evenness of the height increment figures also seems to indicate that, in the main, variations in height of crop from point to point may have been determined more by the degree to which conditions favoured recovery from check after planting, than by the extent to which growth is favoured now that the crop may be regarded as established. Further measurements at a later period in the life of the crop would be of interest in this connexion.

The data regarding the occurrence of disease, given in Tables V and VI, for the normal and the Ursuline types of pine respectively, show that needle disease occurred generally, but that die-back of branches and stems, which is also accompanied by a certain amount of canker development, occurred locally. Table VII records the proportion of diseased trees in an area which lay adjacent to the

850-foot point on the transect. The transect line began in a slight hollow and ended on the relatively flat plateau top; the 850-foot point was just on the latter. The percentages of trees affected by disease are higher in the hollow and on the flat top than elsewhere. This is true for both types of disease and is most marked for the normal type of pine. Very slight traces of die-back on the normal type of pine were found adjacent to, but outside, the sampling area at the 950-foot point. No fungus was observed fructifying on the diseased needles in 1944, but in 1945 *Hypodermella sulcigena* was found on some trees.

The greater severity of disease at either end of the transect than in the middle is undoubtedly associated with the changing topography of the area crossed. It is, however, also interesting to consider its relationship with the condition of the crop at the time of sampling. This may be done by examining the relationship between the height of the crop dominants and either the proportion of trees affected, or the mean height from the ground to which the crowns of trees were affected, by disease. The crop dominants are provided by the normal type of pine and their height at any sampling point is taken as being given by the mid-point of the height-class in which the 90 percentile occurs (Table III). The relationships referred to are illustrated in Diagrams 1 and 2 (data in Tables III and V). These show that there is a decided tendency for both the proportion of trees affected and the height above ground to which trees were affected by disease to increase as the height of the dominants increases. It will be noted also that the crop reached that stage in which its physical constitution, as determined by height growth, favours the development of disease, in topographical positions which promote the occurrence of relatively stagnant air, viz. the slight hollow at the beginning and the flat top at the end of the transect. It has already been noted that these are positions in which soil conditions have favoured relatively fast growth. It would appear, thus, that conditions generally conspire to make those places in which early growth is relatively good, those in which disease is particularly likely to occur. This may be accounted for, at least in part, by the effect of the crop, as it enters the thicket stage, upon local climatic conditions and especially upon air circulation.

It may be noted here that the association of the needle disease with the better grown parts of the crop was demonstrated markedly in Corsican pine in Rothbury Forest (Northumberland) in 1944. *Hypodermella sulcigena* occurred abundantly on the affected needles and seems to be the probable cause of disease. There was no die-back or canker on stems at this place.

Further evidence with regard to this matter is given by the associations demonstrated in Tables VIII to XI. Table VIII shows that the normal type of pine, taking all samples together, was diseased to a significantly greater extent than was the Ursuline type. The reason for this is not known, but it need not follow that the latter type is necessarily always more resistant to disease. Table IX shows that there is a significant association of disease with the regions in which the subsoil is generally poorly drained; this confirms what has been stated above. Tables X and XI, however, show that the main cause of this significance lay in the large proportion of the diseased trees among the normal type pines in regions where

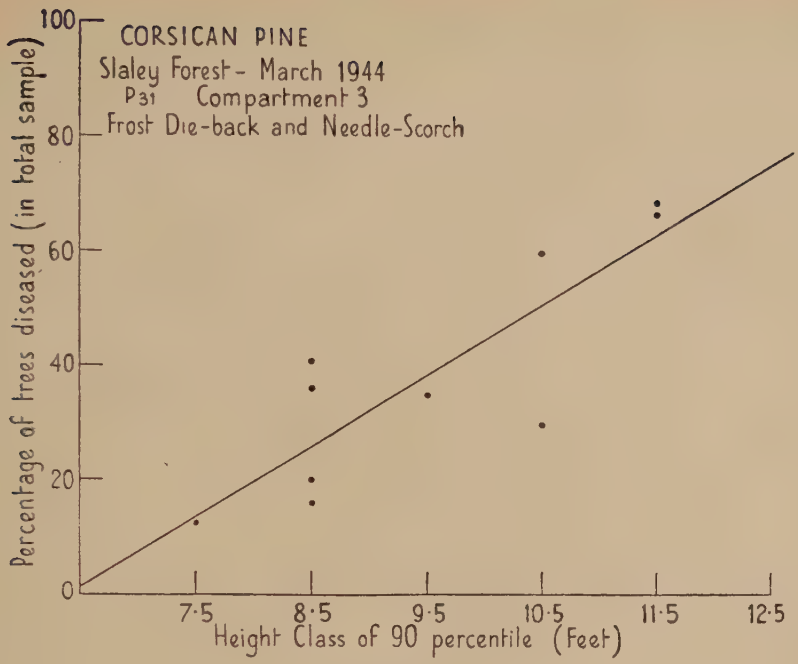


Diagram 1

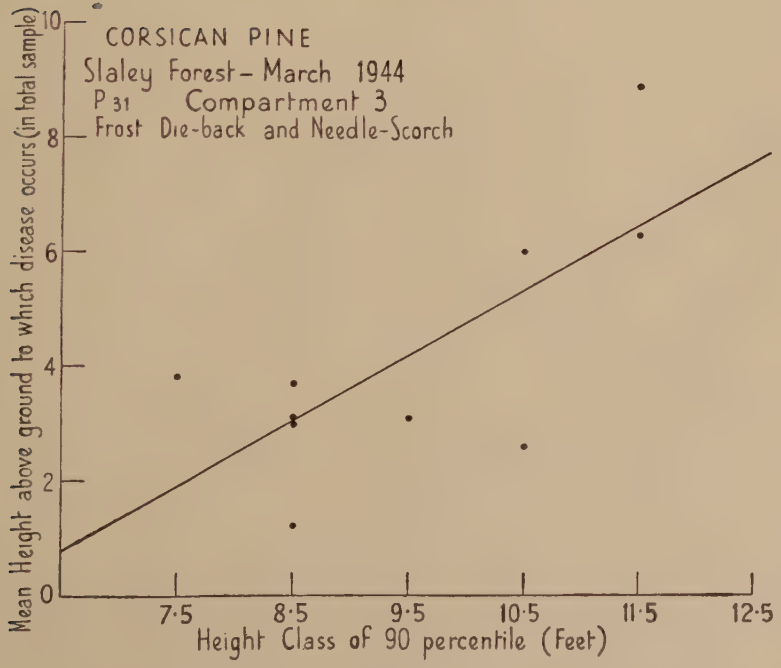


Diagram 2

the subsoil drainage is impeded: there was no similar significant association with the Ursuline type.

There is some interest, also, in the side of the crown which was affected in diseased trees. Tables V and VI show that the crowns of most trees were equally affected on all sides. When, however, those trees which were affected one-sidedly are considered, the eastern side is most affected in the case of the normal type pines and the southern side in the case of the Ursuline type. It is to be noted that the eastern side predominates with both types at the beginning and eastern end of the transect where, owing to topographical position, exposure to easterly winds is most to be expected. Similarly, with both types, trees in which the southerly side is affected occur mostly in the latter part of the transect, where the initial hollow had been surmounted, and the transect crossed the open plateau top, with considerable exposure to the south. It seems to be possible from this that the occurrence of disease is related, at least to some extent, with exposure to winds coming from particular directions, the dangerous direction being determined largely by topographical position.

Since the survey was made upon which this discussion is based, there has been a considerable extension of damage to the crowns owing to injury by late frost in 1945. Growth began early in this year owing to the warm weather in early April, and the severe frost injury was as much a consequence of this as of the low temperatures.

2. *Rheola Forest, Carmarthenshire*

A narrow belt of Corsican pine crosses part of this forest for some distance, eventually reaching the locally high elevation of 1,300 feet, near to the upper planting boundary. Disease caused by frost has occurred in the more elevated end of this belt, data regarding which are given in Table XII. This table is based upon information obtained by taking a sample of six trees every 100 feet, beginning at the upper end of the belt and continuing downwards until outside the zone affected by disease. It will be seen that the disease is concentrated mainly at the upper and, actually, gently undulating end of the belt, and ceases when the steeper middle slope is reached at an elevation of about 1,000 feet. The decrease in height with increase in elevation is correlated with increase in exposure to strong wind and decrease in soil quality and is not caused by the disease. The middle of a long slope is commonly a relatively warm zone, as Cornford demonstrated (5 (*a*)), and the above observations provide an example of this. They also show that, as Cornford found, the upper part of a slope may be a somewhat dangerous situation. The worst injury occurs, however, where it is to be expected, viz. on the flattish shelf at the more elevated end of the belt.

Table XIII gives information collected from eleven crowns sent from this pine belt in November 1944. All except one of these had the top seriously cut back by frost: apart from this a considerable number of leading shoots on side branches had been killed. Table XIII also gives the number of cankers caused by frost injury, found on these specimens. These are classified according to whether they occurred at a node or on an internode. The years indicate the position on the tree

in which the cankers occurred and not necessarily the year in which their development commenced. It will be seen that, in the later years, there was a marked tendency for cankers to develop at the node rather than in the internodes; this was especially obvious on some specimens. The larger cankers occurred in the earlier years and nearer the base of the trees. This tendency to injury at the node seems to be characteristic of Corsican pine. Thus small injuries, which give evidence of having arisen in the autumn, may commonly be found at or very near the node on trees in Corsican pine plantations. The abnormal anatomy of these injuries suggests that early frost may play at least some part in their development. *Dasyscypha calyciformis* may sometimes be observed on the dead tissues surrounding the injury. Proof of any parasitic association has yet to be obtained.

It was also characteristic of the pine at Rheola that the rough-fissured frost-injured bark, which occurred on the lower part of the trees, was most markedly developed on one side of the stems and often most severely around the nodes.

When this pine belt was first examined in 1942 some of the trees had died back recently, and their dead or dying tops were actively occupied by *Pissodes* larvae. There has been no sign, however, of the weevils extending their activity beyond the severely frost-injured parts of the trees. There has been, also, a certain, but quite unimportant amount of damage to shoots by *Myelophilus piniperda*, the pine-shoot beetle. This association of *Pissodes* infestation with frost injury is usual and may always be expected if the injured stems are large enough to favour weevil colonization.

SUMMARY.

The work reported on above has shown:

1. That frost injury, which occurs principally in the autumn, is responsible for a serious dying back of the crown of Corsican pine (*Pinus laricio* var. *Corsicana*). This disease is widely distributed over the west and north of England and Wales. Examples of it have also occurred in the midlands (Nottinghamshire) and in East Anglia, but, so far, their importance has been relatively slight.

2. The disease may simulate in type that ascribed to *Brunchorstia destruens*, and it seems to be probable that, at least sometimes, infection by this fungus, or by similar fungi such as *Cenangium abietis*, follows frost injury. A needle scorch which is associated in various situations with several fungi, sometimes, but not necessarily, accompanies frost injury to the branch system. The manner of development of this has still to be determined.

3. Trees affected by die-back often bear larger or smaller cankers on the branch system. There is a tendency for these to occur more frequently in the region of the nodes than elsewhere. These cankers are one aspect of frost injury: they can occur on trees which show no die-back. The development of rough-fissured bark where smooth bark should appear is also a feature of stems which have been injured but not killed. Not infrequently this rough bark is more severe in the region of the node than elsewhere. It is usually characterized by resin exudation.

4. It is usual for the dead parts of trees to be infested with bark beetles and

especially with *Pissodes* weevils and the pine-shoot beetle, *Myelophilus piniperda*. These beetles are of completely secondary importance under the circumstances.

5. As in all cases of frost injury, the disease occurs with particular severity in situations which favour the occurrence of severe night frost. The severity of the frost is also influenced by the state of the crop. Young crops, in which the free movement of air is unhindered, tend to suffer much less severely than the older ones which have entered, or are about to enter, the thicket stage. Because of this the better grown parts of the crop may be the first to be severely affected.

6. The internal, as well as the external, symptoms of frost injury which results in die-back are listed above. The final diagnosis of this disease often depends on a reading of the abnormal tissues which develop within the tree.

7. Cases of disease in Slaley Forest in Northumberland, and in Rheola Forest in Glamorganshire, are discussed in some detail. The coincidence of factors which favour growth and the occurrence of frost injury are demonstrated at Slaley Forest. Silvicultural data is also presented for the pine in the affected area. In Rheola Forest the poorer growing trees have suffered most severely; this distribution of injury is entirely related to topographical position and not to rate of growth.

8. This examination of frost injury has made it plain that great care must be taken in the use of Corsican pine in many parts of England and Wales. The more upland regions show themselves as being particularly dangerous; but severe injury may occur in lowland parts, providing the topography of the area favours the occurrence of damagingly low temperatures. The south-eastern quarter of England has been free from any but locally serious injury so far. It is possible that this relative freedom from disease may be related to an earlier cessation of growth correlated with the higher summer temperatures which are typical of this part of Britain. This is a matter for future investigation. The general conclusion is that, especially in the west and north, Corsican pine should be confined to topographical situations which do not favour the occurrence of severe low temperatures and to the lower elevations.

Thanks are due to many foresters, both in State and private woodlands, for their courtesy in facilitating field investigations, and to Dr. R. N. Chrystal for the survey, from the entomological standpoint, of numerous specimens sent in to the laboratory. Mr. F. H. Jones has been associated with the collection of much of the field data and the examination of some areas affected has been done in conjunction with Mr. R. G. Sanzen-Baker, Research Officer for England and Wales, Forestry Commission.

LITERATURE REFERENCES.

(1) Bavendamm, W.: 'Bemerkenswerte pilzliche Krankheiten der letzten Jahre.' *Mitt. deut. Dendrol. Ges.*, 180–1, 1934.

(2) Birch, T. T. C.: *A Phomopsis Disease of Conifers in New Zealand.* New Zealand State Forest Service Bulletin, No. 7, 1938.

(3) Bowen, P. R.: '*Cenangium abietis*, *Brunchorstia destruens*, and *Crumanula abietina*'. *Proc. Pa. Acad. Sci.* xiv. 95–9, 1940.

(4) Boyce, J. S.: *Forest Pathology.* New York and London, 1938.

(5) Chronique Forestière: '*Brunchorstia destruens* Eriks. sur *Pinus sylvestris* L.' *Bull. Soc. Centr. Forest. Belgique*, xxxvii. 2. 91, 1930.

(5a) Cornford, C. E., Katabatic Winds and the Prevention of Frost Damage. Q. Jour. Roy. Met. Soc. 1938, 64, 553–87.

(6) Day, W. R.: (*a*) 'Damage by Late Frost on Douglas Fir, Sitka Spruce and other Conifers'. *Forestry*, ii. 1. 1928.

(*b*) 'The Relationship between Frost Damage and Larch Canker.' *Forestry*, v. 1. 41–56, 1931.

(7) Day, W. R., and Peace, T. R.: (*a*) *The Experimental Production and the Diagnosis of Frost Injury on Forest Trees.* Oxford Forest Memoir, No. 16, Oxford, 1934.

(*b*) *Spring Frosts.* Forestry Commission Bulletin, No. 18. H.M.S.O., London, 1937.

(8) Ettlinger, L.: 'Das Triebsterben der Kiefern und sein Erreger.' *Ber. Schweiz. bot. Ges.* liii. 469–70, 1943.

(9) Geiger, R.: *Das Klima der bodennahen Luftschicht.* Braunschweig, 1927.

(10) Hiley, W. E., and Cunliffe, N.: *An Investigation into the Relation between Height Growth of Trees and Meteorological Conditions.* Oxford Forestry Memoir, No. 1. Oxford, 1922.

(11) Jørstad, I.: 'Furuens knopps- og grentørka.' Suppl. to *Tidsskr. for Skog-bruk*, 1929, iv. 1–25.

(12) Lagerberg, T.: *Granens topptorka.* Reports Swedish Inst. Experim. Forestry, 10, 1913.

(13) Langner, W.: 'Untersuchungen über Lärchen-, Apfel- und Buchen-Krebs.' *Phytopatolog. Zeitschr.* ix. 111, 1936.

(14) Leach, J. G.: *Insect Transmission of Plant Diseases.* New York and London, 1940.

(15) Leven, G.: 'A Die-back Disease on Pines (*Brunchorstia destruens* Eriks.).' *Quart. Journ. For.* xxvi. 3. 225–31, 1932.

(16) Liese, J.: (*a*) 'Neue Beobachtungen über *Cenangium abietis*.' *Zeit. f. Forst- u. Jagdwesen*, xliv. 227–9, 1922.

(*b*) 'Auffallende *Cenangium* Erkrankung der Kiefern Keim-pflanzen in Pommern und der Grenzmark.' *Deutsch. Forstzeit.*, xlvi. 21. 535–6, 1931.

(17) Morgan, M. F.: *Chemical Soil Diagnosis by the Universal Soil Testing System.* Bull. Conn. Agric. Expt. Sta., No. 450, 1941.

(18) Schoenwald, R.: 'Wahrnehmungen über das Triebschwinden der Kiefer (*Cenangium abietis* Pers.) in den Jahren 1926–28.' *Deutsch. Forstzeit.*, xlvi. 19. 484–5, 1931.

(19) Schwarz, F.: *Die Erkrankung der Kiefer durch Cenangium abietis.* Jena, 1895. (See also Sorauer, *Handbuch der Pflanzenkrankheiten*, ii. 698–9, 6 ed.)

(20) Steven, H. M.: 'Corsican Pine in Great Britain.' *Forestry*, viii. 1. 14–24, 1934.

(21) Van Vloten, H.: '*Brunchorstia destruens* Eriks. on Scots pine in Scotland.' *Scot. For. Journ.* xliii. 2. 157–8, 1929.

(22) Waldie, J. S. L.: 'A Die-back disease of Pines.' *Trans. Roy. Scot. Arb. Soc.* xl. 2. 120–5, 1926.

TABLE I

Name of forest	*County*	*Topographical type*	*Approx. elevation a.s.l.*	*Relative elevation*	*Stage of crop*	*Degree of die-back*
Allerston	Yorks., E. Riding	Moderately steep slope on plateau edge	650	High	Small pole	Locally severe.
Fewston Reservoir Plantations	Yorks., W. Riding	Plateau	975	,,	Pole	Moderately severe.
		Moderate upper slope	900	,,	Thicket	Severe.
		Mid-slope of wide valley	850	Mod. high	Pole	Very slight or none.
		Bottom of small valley	850	Low	Thicket	Very severe.
		Upper slope above reservoir	600–650	High	Pole	Slight or none.
		Shelf on mid-slope above dense Sitka spruce and lower slope by reservoir	500–600	Mod. low or low	,,	Very severe.
Derwent Valley Water Board Plantations	Derbyshire	Deep folds in a steep lower slope	1,000	Low	Small pole	,, ,,
Delamere	Cheshire	Bottom of a small valley	350	,,	Small trees; no canopy formed	,, ,,
Llantrissant	Glamorgan	Plateau	850	High	Pole	Moderately severe locally.
		Upper slope of narrow valley	650	Mod. high	Thicket	Locally severe.
Rheola	,,	Plateau edge	1,250–1,300	High	,,	Locally very severe.
		Upper slope	1,000–1,250	Mod. high	Small pole	Slight; locally severe.
		Mid-slope	1,000 and less	,, ,,	,, ,,	None.
Pembrey	Carmarthen	Coastal sand-dunes	50	Low	Thicket	Very slight, occasionally severe.

TABLE II. *Corsican Pine in Slaley Forest*

Position on transect (feet)	*Number of trees in sample*		*Angle of slope (degrees)*	*Depth of free-rooting material (inches)*	*Horizons showing impedance in drainage*	*Constitution of 'C' horizons*	*Rooting horizons*	*Soil group*
	Normal type	*Ursuline type*						
0	21	24	3	11	C	Clay	A_0 and top of A_1 and the B horizon for Corsican pine. A as a whole for *Calluna vulgaris*	Podsol, usually with impedance in drainage in one or more horizons and with no clearly developed B_1 horizon.
100	28	26	3	9	(A_2–B_2) and C	,,		
200	23	31	4	6	B_2	Gritstone		
300	34	24	3	9	C (slightly)	Clay		
400	24	24	2·5	8·5	B_2	Gritstone		
500	24	27	2	5·5	B_2	,,		
600	15	28	1	5·5	(A_2–B_2) and B_3 with imperfect drainage	,,		
700	26	23	1	7		,,		
800	24	25	1	10		,,		
950	38	10	0	13·5	C	Clay	A and B for Corsican pine; A for *Calluna*	Degraded brown earth

TABLE III. *Corsican Pine in Slaley Forest*

Position on transect (feet)	*Normal type*				*Ursuline type*			
	Mean total height (feet)	*Height class in which 90 per-centile occurs (feet)*	*Coefficient of variance†*	*Mean height increment for years 1941–3 (feet)*	*Mean total height (feet)*	*Height class in which 90 per-centile occurs (feet)*	*Coefficient of variance†*	*Mean height increment for years 1941–3 (feet)*
0	7·6	10·5	35	3·2	4·2	6·5	30	2·0
100	8·7	11·5	25	3·4	4·5	6·5	29	2·1
200	7·4	10·5	33	3·2	3·7	5·5	26	1·9
300	7·1	8·5	30	3·0	4·4	6·5	30	2·3
400	5·8	7·5	17	2·7	4·1	5·5	39	2·1
500	7·5	9·5	19	3·2	4·3	6·5	36	2·3
600	6·3	8·5	24	3·2	4·1	5·5	30	2·2
700	7·2	8·5	16	3·2	5·6	7·5	23	2·5
800	6·6	8·5	24	3·0	4·8	6·5	28	2·3
950	9·3	11·5	21	3·8	7·1	8·5	22	3·4

† The coefficient of variance $= \frac{\text{Standard Deviation}}{\text{Mean}} \times 100$.

TABLE IV. *'Morgan' Tests on Soil Samples from Slaley Forest*

Point on transect (feet)	*Soil group*	*Soil horizon*	*Chief horizons containing C. pine roots*	*Mean depth at which sample was taken (in.)*	pH	NO_3	NH_3	PO_4	K	Ca	Mg	*Total iron*	*Ferrous iron*
0	Gleyed podsol	A_1	A_0–A_1 and B	2	3·81	4	1	2	—1	Trace	2	10	1
		B_2		9	3·74	1	1	2	0·5	Nil	2	6	1
		G		22	3·82	1	1	2	0·5	Nil	2	5	1
350	Podsol	A_1	,,	2	3·71	2	1	2	—1	Trace	4	8	1
		B_2		9	3·87	1	1	2	0·5	Nil	2	6	1
		C		17	3·85	1	1	2	0·5	Nil	1	5	1
850	Gleyed podsol	A_1	,,	1	3·55	2	1	2	1	Trace	4	9	1
		B_2		11	3·64	1	1	2	0·5	Nil	2	6	1
		G		20	3·70	1	1	2	—1	Nil	2	5	1
950	Degraded brown earth (gleyed)	A_0		1	3·58	2	1	2	—1	Trace	4	8	1
		A	All horizons at least to 24 in. depth	3½	3·70	1	1	2	—1	Nil	2	6	1
		G		15	3·72	1	1	2	—1	Nil	2	5	1

Note. The figures in cols. 6–14 refer to the relative amounts of substances present in the soil:

10 and 9	Very high
5 and 6	Moderately high
4	Medium
2	Low
1 and —1	Very low

TABLE V. *Data relative to Disease*

Position on transect (feet)	Normal Corsican pine: Number of trees: Total in sample	Number of trees: Diseased	Per cent. Diseased	Number with diseased: Shoots	Number with diseased: Needles	Side of crown affected: All round	N.	S.	E.	W.	Mean height (feet) up from ground to which crown was affected	Normal Corsican pine plus Ursuline: Percentage of trees diseased	Mean height (feet) up from ground to which crown was affected
0	21	12	57	9	4	8	2	..	3	..	4·0	60	2·6
100	28	26	93	4	26	24	..	..	2	..	7·4	67	6·3
200	23	12	52	..	12	12	..	..	..	..	6·1	30	6·0
300	34	15	44	..	15	13	..	..	2	..	3·4	36	3·7
400	24	4	17	..	4	3	..	..	1	..	2·9	12·5	3·8
500	24	9	37	..	9	3	..	1	5	..	3·5	35	3·1
600	15	3	20	..	3	2	..	..	..	1	1·0	16	1·2
700	26	13	50	..	13	8	1	1½	2	½	3·2	41	3·0
800	24	3	12	..	3	2	..	1	..	..	3·3	20	3·1
950	38	28	74	..	28	27	..	½	½	..	9·2	69	8·9

TABLE VI. *Ursuline Corsican Pine-data relative to Disease*

Position on transect feet	Number of trees: Total in sample	Number of trees: Diseased	Per cent. diseased	Number with diseased: Shoots	Number with diseased: Needles	Side of crown affected: All round	N.	S.	E.	W.	Mean height (feet) up from ground affected
0	24	15	62	8	8	10	1½	½	2½	½	1·9
100	26	10	39	2	10	10	..	..	..	..	3·4
200	31	1	3	..	1	1	..	..	..	..	5·0
300	24	6	25	1	6	4	..	1	1	..	4·5
400	24	2	8	..	2	2	..	..	..	..	5·5
500	27	9	33	..	9	6	..	3	..	..	2·7
600	28	4	14	1	4	2	..	1	..	1	1·4
700	23	7	30	..	7	5	..	2	..	..	2·9
800	25	7	28	..	7	4	..	3	..	..	3·0
950	10	5	50	..	5	5	..	..	..	..	7·7

TABLE VII. *Assessment of Disease in Corsican pine near 850 feet point on transect line*

	Number of trees				
	With die-back of shoots		With needle scorch only		
Healthy	Severely	Slightly	Severely	Slightly	Total
30	8	9	3	40	90

TABLE VIII. *Association of Disease with Type of Pine Slaley Forest. Corsican pine.* P. 31. C. 3

	Condition of tree		
Type of pine	Healthy	Diseased	Totals
Normal	132	125	257
Ursuline	176	66	242
Totals . . .	308	191	499

$\chi^2 = 24{\cdot}08$. P is less than 0·001

TABLE IX. *Association of Disease with Type of Drainage, among Normal Pines*

	Condition of tree		
Type of sub-soil drainage	Healthy	Diseased	Totals
Impeded	51	93	144
Free.	81	32	113
Totals . . .	132	125	257

$\chi^2 = 33{\cdot}33$. P is less than 0·001

TABLE X. *Association of Disease with Type of Drainage among 'Ursuline' Pines*

Type of sub-soil drainage	*Condition of tree*		*Totals*
	Healthy	*Diseased*	
Impeded	78	37	115
Free.	98	29	127
Totals . . .	176	66	242

$\chi^2 = 2{\cdot}65$. P is between 0·20 and 0·10 (nearly 0·10)

TABLE XI. *Association of Disease with Type of Drainage in Total Sample*

Type of sub-soil drainage	*Condition of tree (all together)*		*Totals*
	Healthy	*Diseased*	
Impeded	129	130	259
Free.	179	61	240
Totals . . .	308	191	499

$\chi^2 = 40{\cdot}0$. P is less than 0·001

Analysis of a full contingency table (giving 'Healthy' and 'Diseased' classes for both 'Normal' and 'Ursuline' type for all positions on the transect) gives a probability of independence in distribution of the two types of pine between 'Healthy' and 'Diseased' classes, and of these classes between the various positions, of much less than 0·001 ($\chi^2 = 1626{\cdot}05$; $n = 27$. χ^2 for $P = 0{\cdot}001$ is 55·476).

TABLE XII. *Data regarding Corsican Pine affected by Die-back, caused by Frost Injury, in Rheola Forest, Glamorganshire*

Distance along transect (feet)	*Range of elevation (feet)*	*Range of slope (degrees)*	*Number of samples of 6 trees each*	*Mean total height (feet)*	*Percentage of die-back in samples*		*Number of affected trees adjacent to samples*	
					Total affected	*Severely affected*	*Moderately affected*	*Severely affected*
560	1,300–1,260*	0–6	6	8·5	76	36	3	4
600	1,260–1,180*	6–10	6	13·0	33	3	9	..
500	1,180–1,055	8–18	5	16·2	22	11	1	..
500	1,055–970	6–18	5	18·7	0	0	..	..

* Exposed position; *Molinia caerulea* is abundant locally. Elsewhere vegetation is mainly bilberry with fine grasses.

TABLE XIII. *Data regarding Frost-injured Corsican Pine in Rheola Forest*

Number of	*Year**							
	1944	*1943*	*1942*	*1941*	*1940*	*1939*	*1938*	*1937*
Leading shoots killed	2	8	11	12	12	9	..	..
Cankers at nodes	..	..	3	7	5	2	0	1
Cankers on internodes	..	..	0	2	4	4	9	4

* This indicates position on crown and not date of occurrence.

WEEDING AND CLEANING

By W. L. TAYLOR, C.B.E.

AS with most of forestry's routine tasks, the weeding and cleaning of plantations are, prima facie, operations of a simple nature. The objects are to protect the young crop from being smothered or otherwise interfered with by wild vegetation (Weeding), and as the plantations progress to keep them free from intrusive growths of bramble, briar, and honeysuckle and any coppice shoots, natural saplings, or other unwanted growth that may occur among the planted species (Cleaning).

It goes without saying that weed competition can do untold harm in a young plantation, even to the extent of ruining the whole planting. Annual and other herbs often threaten to overwhelm small newly planted trees by the sheer weight of their lush growth, while dense growths of the stiffer-stemmed kinds of weeds are also frequently damaging.

All wild plants growing in a forest that are not necessary or helpful to the formation of the prescribed crop come under the general heading of forest weeds, although not all those that may be present are actually inimical. When surrounded by lusty weed species possessing all the advantages to be derived from an accustomed habitat, a young plantation which has not yet established itself is at considerable disadvantage in its early fight to attain supremacy, a handicap which extends below ground as well as above because root competition is also severe.

Foresters have to contend with numerous types of weeds, annual and perennial, herbaceous and woody, and trailing and climbing. In a new planting the wild herbs, fern, heather, whin, brambles, and coppice shoots are all potential causes of trouble. Bracken fern is one of the most serious foes to a young forest crop. At later stages the climbers, briars, coppice, and minor tree species (intruders) enter into the picture.

Injury in a number of forms results from uncontrolled weed-growth:

Smothering, with exclusion of light and air, resulting in etiolation, breakage, distortion, and in dank conditions under a dense mat of vegetation, to increased risk of losses from moulds and fungi.

Damage to stems, leading shoots, and foliage, by whipping and chafing, resulting in distortions and lesions affecting height and crown development, nutrition and proper growth, and the quality of the timber, besides affording means of access for the spores of fungi.

The premature suppression of side branches and consequent inducement of top-heavy development and instability.

Strangulation by climbing plants.

Enhanced danger from frost where certain types of weeds predominate among the ground flora, e.g. fine grasses.

Competition in the soil for moisture and nutrients, and excessive transpiration of available moisture.

As plantations develop, by the production of whips and weakly stems due to overcrowding.

Weeding and cleaning are described above as routine operations of forestry, but there is, of course, more in the proper supervision of these operations than mere routine. It is necessary to know when to weed, how to weed, and how to decide the more difficult problem of when it can be regarded as safe not to weed. Failures are bound to follow if necessary weedings are neglected. At the same time weeding is a costly operation which must sometimes be repeated twice or even three times in a season and to overdo it becomes unnecessarily expensive; in forestry, as in everything else, a penny *legitimately* saved is a penny earned. In general, the need to weed will be obvious to the forester. It is not so easy to recognize when a weeding can be avoided without risk to the crop, a matter in which both the value of observation and need for experience are abundantly demonstrated and cannot be over-estimated. A point always arrives at which the expense of weeding to save an odd tree here and there in a fully stocked plantation is not justified. If an experienced and observant forester, after carefully assessing the circumstances before him, is confident that his plantation will come to no harm, or a negligible amount of harm, then it may be considered safe to say that weeding is not necessary. But where doubt arises and no other reliable confirmatory opinion is available for consultation, weeding ought never to be delayed. This aspect of the weeding problem is important because a stage is always reached in the early life of a plantation at which the need to weed ceases.

In addition to otherwise unwarranted expenditure on beatings-up to replace trees killed by weeds, the penalty for inattention to timely weeding is, at the best, a weakly, ill-furnished, gappy, and leggy plantation that is more or less unstable and unhealthy; at the worst the planting may have to be written off as a failure. If it is taken as a truism that weeding is always necessary when judgement based on experience points the moral, then, equally, it is wrong to continue to weed blindly season after season as side branches lengthen and height growth draws away from the level of the weeds. *Experientia docet*, but until the required degree of experience is gained it is wise to keep to the safe side.

The essence of all successful silvicultural tending is frequent inspection followed by speedy action where action is called for. Watchfulness is the best of all safeguards against neglect of weedings and cleanings as it is in regard to any other of the seasonal operations of forestry. Weeds grow exceedingly fast, often a few days' growth makes all the difference. On no account must newly planted areas be allowed to get overgrown, nor does it do to be complaisant when the first flush of wild herbage has been dealt with, because secondary summer and autumnal growth may also be lush, particularly during wet seasons. The effects of seasonal vagaries of the weather are apt to make weeding operations more onerous. Weed growth is frequently unexpectedly profuse during a wet and mild autumn, especially on grass areas; again, in a region in which rainfall is normally low, a wet summer season will induce a much stronger growth of weeds than is usual. These are

occasions on which the forester may find himself caught out if he is not careful. Pending establishment it is imperative that no chance of making headway be denied to the crop.

To be fully effective, necessary weedings must be carried out promptly and completed before injury is sustained. Always attend first to the areas in which the most urgent danger lies, never forgetting that a plantation may look safe for the moment and be at risk a few days hence owing to the rapidity with which weed-growth develops. Gaps in a plantation can frequently be traced to patches of weed that have been overlooked, particularly of such weeds as bracken, bramble, gorse, aspen suckers, seedling birches, rose-bay willow-herb, *Aira caespitosa*, *Molinia*, *Juncus*, or *Calamagrostis*. All these often occur quite locally in plantations; such patches may need weeding for some years after the rest of the area is safe.

Do not be caught napping. Weeding-gangs should be directed daily to the areas most in need of attention and not left to plod their way stolidly through the plantings without regard to day-to-day local conditions. The nuisance value of a weed depends largely upon its luxuriousness and density, and it is the 'pure' patches of strong-growing weed species that are the chief danger.

The method used in planting influences risk from weeds to a considerable extent, as will be seen in turf-planted areas or where planting is done along the ridge, or at the side, of the furrow on deeply ploughed land. In these circumstances the young plants have a much better chance of holding their own than they have when planted on the flat in the midst of a well-established natural ground flora.

The types of weed-growth present on the ground, the densities in which they grow, the species of tree planted, the method of planting, and the progress of the plantation are the notable factors. In certain circumstances a moderate amount of stiff-growing weed affords temporary shelter from sun, frost, and wind; consequently there may be benefits to be obtained on occasion by intelligent manipulation of weed-growth of this description, but no suspicion of smothering or overcrowding can be tolerated. For instance, heather and bilberry will give protection from blast on exposed heaths and any weed-growth there may be on open chalk downland affords shelter from sun-scorch that is of especial help to beech. Weeds with a tendency to flop over the young crop are potentially harmful in almost any circumstances in the first few years.

Stool shoots are the bugbear in coppice areas. Of coppice weeds chestnut is the greatest aggressor if neglected; lime, oak, birch, and ash come next in order. Expertly handled moderate coppice growth is capable of affording protection to and nursing up some species of hardwoods, but in the great majority of cases, in conifer plantings in particular, it pays best to deal drastically with coppice shoots until the stools are so weakened as to become harmless or until the crop finally overtops all weed-growth of this description. In the first years the only sensible thing to do is to keep the stools closely cropped by slashing away all annual growth as it occurs; the slower an introduced species is to establish itself the more necessary it is to be ruthless with coppice. Where the annual shoots of coppice

are cut while still sappy the stools are weakened more quickly. Gorse and broom also require drastic treatment.

Young conifers need complete freedom to expand their successive whorls of branches until the plantation begins to close in, and they must have clear headway for their leading shoots. If leaders are interfered with and the natural leaf-spread restricted at this period, development is bound to suffer and the general health and well-being of the plantation is imperilled.

It is very important to realize that pines and larches must be weeded *early* in the season and kept completely clean from weeds for the first years. Attention to the spruces can usually be deferred until rather later in the season because, during the first weeks of summer, they will not suffer from weed-growth that would be irretrievably damaging, for instance, to Scots pine and European larch in the same period.

Young hardwoods also require light, air, and space, but everything is not yet known about weeding requirements and weeding technique in regard to young oak, beech, and ash, in all the various vegetative conditions which prevail on soils for which these trees are suited. Where small transplants or seedlings are used there is no doubt that oak and beech must at first be weeded early and thoroughly. Ash and sycamore are (or should be) taller when planted out and for them the urgency on the average site may not be quite so serious. Nevertheless, hardwood species must not be permitted to become overwhelmed by weeds to the detriment of their spring and summer growth. Nearly all young broad-leaved trees are highly susceptible both to late frost and drought and in some conditions undoubtedly appear to benefit from the shelter of a moderate amount of natural growth round about. In this there is room for more recording and assessment of the results of further observation; the one thing that is certain is that all species of young trees need to be given light and air and the growing-space proper to their several requirements at all stages of growth.

But, apart from smothering, weed-growth on naturally dry soils, especially coppice, tends to draw more than its share of moisture and is capable of drying out the surface soil excessively. This has been suggested as one of the major factors accounting for the indifferent success of the replanted mixed belts in East Anglia.

Weeding may be complete, that is to say all adventitious growth on the area is cut back, or it may be selective around individual plants needing more freedom. It is usual to cut all excessive weed-growth at least in the first and second year's weedings. As already stated, the crux of the matter is to be able to realize when weeds are harmful and when the young planting can be regarded as so far established as to be free from weed dangers.

When the crop has begun to close in it is time to begin to think about cleaning. In afforestation there is usually a gap of at least 5 years—it may be as long as 10 years—between the last weeding operation and the first cleaning, but in some types of plantations there is no hard-and-fast dividing line between the two operations; in such conditions it may be hard to define where weeding ends and cleaning begins.

Cleaning a plantation is the operation of cutting out the taller growing, woody,

weed species, climbers, and naturally regenerated stems that are redundant where not of use to make good gaps in espacement either temporarily or to take a definite place as part of the forest crop; intrusive birch and other hardwoods can sometimes be utilized to fill up in these ways. What is necessary is to prevent overcrowding and injury to the planted trees and to facilitate access for inspection within the plantation which at this stage, as in the earlier and most of the subsequent stages, should be frequent. If his footprints are the best dressing a farmer can give his land, then the forester's eye affords the best assurance against forest ills. Frequently one cleaning suffices, any further unwanted tellers and coppice poles being removed in course of the early thinnings. The operation is one for the winter months.

At this period it is usually convenient to cut regular 'racks' across the compartment to give access to the interior for inspection purposes. If the crop is sufficiently advanced, cleaning is combined with brashing, or the knocking or cutting off of the lower suppressed branches throughout the plantation, preparatory to marking a first thinning, to afford freer circulation of air, and to give protection against fire at this hazardous stage. Opportunity can also be taken to cut out the more obvious of the genetically bad, excessively branchy, or distorted trees—stems that must in any case be removed in the near future—although the general warning that every strong-growing tree, otherwise of good type, is not of necessity a 'wolf' tree must not be ignored. Foresters must be guided by circumstances in attempting to combine these operations, also in regard to the extent of brashing that is necessary; cleanings cannot, however, always be allowed to wait. However, where cleaning has been deferred to a relatively late stage, brashing will be found essential to enable workers to penetrate into the plantation.

The choice of tools for weeding and cleaning is not very wide. For weeding, the short-handled bagging or reaping hook, of which there are several patterns, is much superior to the long-handled tool, and if used with a stick or crook carried in the left hand for freeing individual tree stems it is certainly the best all-round weeding-tool in general use. With the long-handled hook there is less control, but with either type, if badly handled, it is possible to slash off leaders and maim large numbers of young trees—in inexperienced or careless hands the 'Sheffield rabbit' can be almost as destructive as its living counterpart.

Existing types of mechanical weed-cutters have a limited field of utility in the plantations. The Allen motor-scythe and others have their uses on relatively level ground where the weed-growth is composed mainly of grasses and other soft herbs, but to enable these power tools to be used effectively the plantings must be regular and the rows well defined. In most cases mechanical weeding requires supplemental hand-weeding between the trees to make a good job of it.

The proper tool for cleaning is the bill-hook, of which there are many local types. Like all edged weapons, a bill-hook is only effective in experienced hands; indeed, if unnecessary damage is to be avoided, and the risk of personal accident reduced, no worker should be allowed in the plantation with a tool with a cutting edge until he is thoroughly accustomed to its use. Unless the workers are highly

skilled it is always advisable to make use of the hand-saw for brashing persistent side branches.

All weeding and cleaning tools should be kept clean and sharp or slipshod work may confidently be looked for. Tools should be wiped and oiled after the day's work and the hone applied as soon as edges give sign of becoming dull. Saws must be kept properly set.

Both weeding and cleaning impose hard wear on clothing. Materials should be as resistant to thorn and briar as possible, and to wet conditions, because weed-growth is often saturated with rain or dew. For weeding, rubber Wellingtons are suitable; strong leather boots and leggings are advisable for cleaning work.

NEGLECT OF NATURAL REGENERATION

BY RAY BOURNE

DURING the past season, in south-east England, two phemonena have occurred which are of considerable significance in forest practice. First, the beech mast produced in the autumn of 1944 was far heavier than in any seed-year since 1922. The interval of 22 years, which is twice the average sun-spot cycle, may be noted. Secondly, the germination of ash in the spring of 1945 was prolific in closed woods over wide areas, although seed has not been produced in quantity since 1939. Both of these phenomena were undoubtedly associated with peculiarities in the weather, and, in consequence, their recurrence is liable to be relatively rare. Indeed, one or more decades may elapse before foresters are again presented by Nature with such a mass of beech and ash seedlings as many must have observed last spring. Some will surely have wondered whether they should take any steps to save them. A few may actually have carried out operations to that end, but the large majority will probably have trusted to the natural survival of the seedlings and will have done nothing. In very many cases such neglect will soon prove fatal. It is therefore not only of interest but also of importance to describe these phenomena and then briefly to review the problems in practice which arise from them. These matters are discussed in detail in a volume in process of compilation, entitled *The Practice of Mixed Forestry*, a practice somewhat analogous to mixed farming, so that no more detail is presented in this article than is absolutely necessary to an understanding of the immediate subject.

With regard to the beech mast, the certainty of its occurrence was apparent towards the end of October 1944, when the seed began to fall in quantity. In a series of sample counts, roughly one-half of the nuts were found to be full on the average. When the mass of the seed fell in November and December the percentage of full nuts was then rather higher. In general, the quantity of the seed was greatest where the proportion of the trees with wide crowns was comparatively high. On large trees the abundance was greater on the relatively dry soils, whether acid gravels or dry chalks, than on the moist soils. There was very little seed in all the younger woods examined, but there was definitely more seed, in such cases, on the drier than on the moister soils. Those facts are of considerable interest. In contrast to the great masts of 1912 and of 1922, which followed the exceptionally dry and hot summers of 1911 and of 1921, the mast of 1944 was not preceded by any exceptional summer. But it followed the two very dry springs of 1943 and 1944, which must have affected the vegetative growth on the dry soils more than on the moist soils. Just as moribund beech-trees often produce full nuts when healthy trees have none at all, so a general check to growth may well have resulted in a saving up of food reserves and in the mast of 1944. Since the beech is at or near the northern limit of its natural range in this country, the species is only able to build up a reserve of food materials for full seed production

under exceptional conditions. It would now appear that serious spring droughts can be as effective in this respect as very fine summers. Whether that is the true explanation or not, the fact remains that foresters in Britain cannot always expect a full beech-mast year within one sun-spot cycle of 10 to 12 years, and may have to wait two cycles, or 20 to 24 years. In the treatment of beech woods forest practices must allow for that fact. That truth will be even more apparent when the full story of the 1944 mast has been told.

When checks on the distribution of beech seed and of seedlings were made in the months of December to August 1945, several important points came to light. First, where full nuts lay more or less exposed on the ground in very open woods a large proportion were shrivelled by the phenomenal frosts at Christmas 1944. Where the beech canopy was complete or fairly complete, the exposed nuts escaped damage from frost, but were largely skinned and/or eaten. In contrast, wherever the nuts were covered by litter they generally escaped destruction. In this connexion several examples were noted in closed woods where the nuts, though fully exposed on the surface, escaped destruction by rodents and birds, particularly by the grey squirrel, the wood pigeon, and the chaffinch, because they lay so close to frequented places that the devourers of the seed sought their food in more secluded areas. For instance, in the immediate vicinity of military camps situated in beech woods, little seed would appear to have been destroyed even by mice. Where the seed occurred in mass in such areas, the subsequent germination often exceeded 300 per square yard. But as was perhaps to be expected, beyond a reasonable distance from these camps, varying with the circumstances from about 50 to 200 yards, the quantity of seed eaten was exceptional. Beyond 400–500 yards, abnormal destruction of exposed nuts by rodents and birds ceased. Thus, in ordinary practice, if special steps are taken to protect exposed seed in selected areas due for regeneration, foresters must be prepared for abnormal destruction in the more immediate surround.

Secondly, germination commenced in January in wet litter and continued under drier conditions right through to May and even to June. The main mass of the seedlings only appeared above ground in the first fortnight of April. Wherever the litter was not too deep and was reasonably dry, all the seedlings were well rooted in the mineral soil. The exposed nuts on bare ground, which had survived, produced seedlings which were exceptionally well rooted, even where the surface of the soil had been previously hardened by trampling. On the other hand, wherever a mat of wet leaves lay beneath the litter, either in dense woods, in depressions or ruts in more open woods, or in bramble patches, a considerable proportion of the seedlings remained unrooted in the mineral soil, although they had radicles of 2 to 3 inches in length. They were depending solely on the moisture in the litter and were easily pulled up. Under similar conditions other seedlings were rooted only by the tips of their radicles, the majority of the root-hairs deriving moisture from the wet litter. Seedlings properly rooted in the soil were rare. Irrespective of litter conditions, other than in frequented places, a considerable number of seedlings were eaten by pigeons or pecked by smaller birds on first emergence of the cotyledons while still folded in a ball. Once the cotyle-

dons had opened out, such damage appeared to cease. Where extraction operations of timber and topwood were not completed by the end of March, further removal caused great destruction of seedlings. In the main tracks of the earlier removal, owing to the nuts being pressed into the soil, germination was often delayed till May. Where the felling was not commenced before November, after the nuts were ripe, and where the extraction was completed or was stopped before the end of March, such operations did not greatly affect the establishment of seedlings. Indeed, where moist litter and especially brambles were previously present these operations generally increased the number of seedlings well rooted in the mineral soil. Obviously, by timely timber operations in a beech-mast year, foresters can increase the chances of natural regeneration in bramble areas or in closed woods with deep wet litter.

Thirdly, the late frosts of 22 and 23 April 1945 destroyed practically all the beech seedlings in the open, where they were exposed to the full morning sun. In such areas a few seedlings survived, where they were shaded by brambles or other weed-growth, but their further survival is now endangered by the weeds. In woods with open canopy a considerable proportion of the seedlings were destroyed or badly frosted, particularly on eastern and southern aspects. In such woods with western and northern aspects the destruction and damage by frost was definitely less, but was only negligible where the slopes were relatively steep. In contrast, in woods with a dense or fairly close canopy, irrespective of aspect, frost damage was exceptional. The destruction and damage were caused by the rapid thawing rather than by the severity of the frost. Moreover, later frosts in May caused little further damage in the open woods except in the case of the newly germinated seedlings, which indicates that May frosts would have to be very severe to destroy the main mass of the seedlings. It is of course true that, in the open woods, the majority of the seedlings exposed to early morning sun had already been frosted in April, but general observation, both in April and May, pointed to the conclusion that the seedlings killed outright were those newly germinated. Seedlings which had had 2 or 3 weeks in which to harden, prior to the later frosts, were not destroyed by the rapid thaws, but were only damaged. For fear of late frosts in April, foresters in this country should clearly not open beech woods too heavily in advance of a mast year.

Fourthly, little further change in the beech-seedling population was distinguishable before the middle of June, except where the seedlings were subject to serious trampling. For instance, within the military camps, the vast majority of the seedlings had been destroyed by that date. But from about the middle of June natural casualties among the seedlings became noticeable, and they have continued to be more and more apparent, especially in the areas with relatively deep litter, in which few of the seedlings were properly rooted in the mineral soil. In the latter areas shrivelling of the seedlings has often been observed. In some localities rabbits have undoubtedly contributed to the disappearance of the seedlings. In general, slugs have partially eaten many seedlings and have probably destroyed many more. Here and there seedlings have been bitten by mice, but this has not been widespread. Even in the denser surviving patches, recent counts

have rarely shown more than 100 seedlings per square yard, in comparison with the original 300 or more. The net result by August is that, with certain exceptions, seedlings have survived only in patches large and small, or in groups of a few, or even singly, and are no longer to be seen as carpets over several acres.

A large proportion of the seedlings which have survived have produced no more than the pair of primary opposite leaves and a small terminal bud. It is probable that many of these under shade will fail to shoot again next spring. Wherever there is some measure of sidelight, all such seedlings have definitely turned the primary leaves towards the light, irrespective of the points of the compass. Their terminal buds are usually larger than those of the seedlings under full shade, and it is likely that many of them will shoot in the spring. Some of the seedlings with ample sidelight have developed normally and have produced a secondary shoot with one or more secondary alternate leaves. But it is only under good light conditions that the majority of the seedlings, which survived destruction by frost, have a pronounced secondary shoot with two or three alternate leaves and typical beech buds. With ample light this has occurred whether the seedlings are on ground free of weeds or are growing among dense weeds. They have in no way suffered in competition for soil moisture. Their growth has only been seriously checked by weeds, where tall weeds, such as brambles, bracken, willow herb, and grasses, have overshaded them. In south-east England, at any rate, adequate light is clearly the essential need for the proper development of beech seedlings. Lack of soil moisture could only be feared on the driest soils or in exceptional droughts.

Obviously, weed growth may affect other seedlings than beech, including those of ash, and in consequence further reference to the problem of weeds may be deferred till the case of the ash has been reviewed. Most foresters will remember the phenomenal ash seed-year of 1939 and will have observed the ash regeneration which has established itself over the past 5 years, in spite probably of neglect. Some new germination of dormant seed has occurred annually since 1940, but nothing like the germination in the spring of 1945. Many cases have been observed in various parts of south-east England, in which the ash seedlings have now come up almost like mustard and cress, although there has definitely been very little new seed in those localities since 1939. While there has been a considerable amount of delayed germination in the spring of 1945 in open woods and in openings, the main masses of seedlings have come up either in closed woods, both in high woods and in underwoods, or in recent clearings of such closed woods. It is believed that the severe frosts at Christmas were responsible for this phenomenon, penetrating the soil everywhere to a depth of several inches and cracking the seed covering. Annually since 1939, in the more open areas, alternate heating and wetting of the seed will have cracked the covering of a proportion, resulting in annual delayed germination. In such areas only the balance of seed remaining will have germinated in the spring of 1945. On the other hand, in the closed woods little or no germination has occurred since 1939, and now all the seed has germinated in one season. Frost seems to be the only reasonable explanation of this phenomenon. In this connexion the writer has had no opportunity of checking the germination of ash in the spring of 1945 in areas where snow fell prior to the Christmas frosts, but if germination

in closed woods in such areas has not been exceptional, that would be fair proof of the above suggestion. Any information foresters can furnish on this point would be of great interest. It would certainly appear, however, that the severe Christmas frosts which destroyed many of the exposed beech-nuts actually prepared the way for much delayed germination of ash seed. It is an indication that the freezing of ash seed may be an effective way of promoting germination.

Germination of ash in 1945 was first observed in January and the main mass of the seedlings appeared above ground in the first week of April, about a week ahead of the beech. Neither the seed nor the seedlings would appear to have been destroyed by rabbits and birds to the same extent as with the beech, and, as usual, the seedlings have not been much affected as yet by rabbits. In contrast to the beech again, the majority of the seedlings are well rooted in the mineral soil, even in deep litter, which is a reflection of the fact that the seed had fallen before much of the litter and had lain dormant under its covering. Moreover, though much ash regeneration, including seedlings, was badly frosted by the late frosts of April and May, except under closed canopy, relatively little would appear to have been killed outright even in the open. On the other hand, the ash seedlings were perhaps more excessively destroyed by delayed timber operations than those of the beech. Thus, when it is remembered that ash seed is produced abundantly in this country, both by old and young trees, more frequently than beech mast, it is evident that the problem of ash regeneration is far less complex than that of the beech.

Sycamore is even easier to regenerate than the ash, because the seed years are still more frequent. Delayed germination certainly occurs also with this species, but not to the same extent under shade as with the ash. In all probability, peculiarities of weather will accelerate or retard germination, but the frosts of Christmas, 1944, did not appear to have had much effect one way or the other.

With the oak, both pedunculate and sessile, the production of acorns in the autumn of 1944 tended to be confined to a few trees, except locally on the drier sands and gravels. On the moist soils there were very few acorns anywhere. Indeed, 1944 could nowhere be classed as an oak-mast year. Of the acorns which fell locally in the autumn of 1944, a very high proportion were destroyed by rodents and birds. In consequence, oak seedlings in the spring of 1945 were relatively very rare.

Apart from birch, of which there was generally ample seed, rarity of seedlings in the spring of 1945 was a feature with all other species, particularly with the conifers, such as Scots pine, larch, Silver fir, Sitka spruce, thuja, Lawson's cypress, and tsuga. Thus the problems of 1945 in practice relate primarily to the beech, to the ash, and to some extent to the sycamore.

The first problem is that of weeding. Towards the end of June 1945 the annual growth of weeds, especially of brambles, bracken, and willow herb, had begun seriously to smother many seedling areas. Around bramble patches in particular, the annual outward spread of the runners had grown over seedlings to breadths up to 3 and 4 yards. To save the seedlings in any quantity, it will be essential to cut the brambles back, and for economy in weeding, this should be done before the runners take firm root and reshoot in the spring of 1946. In areas which were weeded

in June, July, and August, the resulting response in the growth of the seedlings is very noticeable, particularly in the areas first cleared. Such seedlings were freed in time for them to develop a secondary shoot this season and to be now 6–9 inches in height. The seedlings freed in the later weedings have grown and look sturdy, but they have rarely produced secondary shoots; however, they are likely to develop rapidly next spring. In the seedling areas still to be weeded, many of the seedlings are somewhat etiolated and it remains to be seen whether they will respond readily in the spring. Nevertheless, it is already clear that such weeding should be early rather than late, and that it would be materially quicker and cheaper if carried out before the weeds become rampant.

With regard to the actual operation of weeding various tools have been tried, but in bramble areas a long-handled and curved hedge-slasher has been found to be the most effective. In contrast to a plantation, the seedlings may be here, there, or everywhere, while larger plants of various species may be scattered among them. By holding the slasher vertically, by pushing its point forward along the ground to pick up the lowest bramble runners, and by cutting upwards, not only are the brambles severed, but the minimum number of seedlings and plants are damaged. If two parallel lines are so cut, 3 to 6 feet apart, it is easy to roll up the brambles, cutting other weeds in the process, and to lift with the slasher and to dump the ball of brambles and weeds in patches without regeneration. Bracken and willow herb, without brambles, are best cut in the usual way with a crook and hook, cutting above the level of the seedlings and taking care to avoid cutting bigger plants. Such operations have not cost more than £2 to £3 per acre. When considering costs, it should be realized that seedling regeneration in quantity is rare in areas already densely smothered in weeds; that patches of rampant weeds with no regeneration need not and should not be weeded unless and until they are to be planted; that there may be patches with neither regeneration nor weeds; and that the actual area in any acre to be weeded may be no more than half an acre. The costs quoted relate to areas in which one-half to two-thirds of an acre, on the average, had to be weeded to ensure satisfactory development of the seedlings. Such weedings, of course, can be continued all through the winter in unweeded bramble areas. However, in all areas weeded, whether sooner or later, there is no doubt that the weedings will at least double the area of regeneration saved. In many areas already weeded it is remarkable how many other species than beech and ash have been saved to grow into a mixture, including oak, wych elm, sycamore, birch, and cherry. In some cases even seedlings of larch and of other conifers have been found among the hardwoods. How many of these areas will require a second weeding in 1946 is not yet known. Some will certainly need weeding again, and it is evident that the earlier the work can be carried out in June, or even in May, the better will be the resultant response of the seedlings. For proper development the seedlings must not be overshaded during the period of most active growth. In no case, however, should it be necessary to spend more than £5 per acre, altogether, in order to establish the regeneration.

Weeding of regeneration will not always suffice to establish it. The provision

of more light through the canopy may be necessary in many cases, and this will involve further fellings over and about the regeneration. An observation repeatedly made in past years, which has been fully corroborated in 1945, is that the regeneration on the north side of a gap, which is relatively well illuminated, is always better developed than that on the south side, which is comparatively shaded. That is a reflection of the northern latitudes of this country, and indicates that, in general, foresters need not be so concerned with the provision of overhead light as with letting in sidelight from the south. In view of the damage caused by early morning sun after late frosts, foresters can best provide the extra light by relatively narrow strip fellings running from south to north, but they should be careful not to make that a general rule. If they want a rule to guide them, let them never allow, in advance of regeneration, too much light to penetrate to a forest floor, clean or relatively clean of weeds. On all but the drier soils in our climates too much premature light may only result in rampant weed-growth. Foresters in this country, who seek to establish natural regeneration, should treasure all areas with a clean forest floor, until they have obtained the regeneration. With beech they must obviously be careful not to keep such areas so dense that litter accumulates to form a wet mat at depth. If they succeed in that by thinnings, they will sooner or later be given the regeneration. Then, as in 1945, they cannot only afford to let in light, but they should often provide more light.

The forester concerned must either make a map, or at least a mental sketch, of the distribution both of the regeneration and of the weeds in a wood. To minimize subsequent damage to the regeneration the writer is generally arranging to fell trees on to the patches of weeds and to extract the timber and topwood along defined tracks as far as possible through the weed areas. Here it may be repeated that little or no regeneration occurs in woods which are already so open that weeds are rampant. In the woods under consideration the weeds are only locally rampant and, because they follow the light, the patches tend to have south to north axes. Recognizing that fact, it will be realized that the procedure outlined above aims not only at letting in the maximum amount of light with the minimum of felling, but also at destroying the weeds in the course of felling and of extraction. These areas, so cleared of weeds at a low cost, will be planted up with surplus natural regeneration or with other suitable species. The general tendency is to fell and to extract along lines running from south to north. It may be repeated, again, that that is not a rule. The one rule, expressed in three words, is 'Follow the Regeneration'.

Apart from the tendency to fell in a definite direction, order is brought into the working by treating each crop as a unit, on its merits, and by limiting the fellings in it to the increment, having regard to the capital. To determine the increment, the trees in each crop must be enumerated and measured at intervals, and accurate records must be kept of the fellings. For over 20 years these figures have been kept for some woods, and they are now being accumulated for many others. The former figures already indicate that, with suitable treatments, the ncrements in 20 years or so may equal the original capitals, a result which is fully

in accord with the modern theories of growing stock, a subject which cannot be considered here. Emphasis, however, should be laid on the frequent need, in cases of intermittent seed production as with the beech in this country, of cutting more than the increment in the seed year and in the immediate succeeding years. A form of intermittent working is an essential consequence of seed production only at long intervals. If desirable, the effect on the annual yield of the forest as a whole can generally be minimized by retarding the fellings in crops not urgently in need of regeneration. Indeed, in such crops, reduced feelings may materially help in ensuring a clean forest floor, when these crops, in turn, become due for regeneration.

In this necessarily brief review of the practical problems arising out of the phenomenal beech and ash regeneration in 1945, it has not been possible even to mention many relevant points, but it is hoped that enough has been written to stimulate many foresters to try and save much of the regeneration with which they have just been presented. There has been a local oak mast in the autumn of 1945, and much that has been written above about beech is likely to apply to the oak. Weeds in oak woods, however, are generally much more rampant than in beech woods, and a preliminary step, essential to success in the former, will be the eradication or weakening of the weeds in winter. In fact, the practice of pannage with pigs in oak woods might be revived with great advantage. Pigs, of course, should not be allowed to disturb good ash regeneration. In addition to the oak, Spanish chestnut and sycamore have produced seed in 1945; hence foresters will not lack opportunities in the next year or two of mixing species and of extending natural regeneration. At the moment much is being said and written of the great cost of replanting in this country. Planting cannot be avoided in many cleared areas or in new afforestation, but there are many 'devastated' woods in which natural regeneration could form at least the basis of the new crops. The forester who fails to establish much natural regeneration in such areas, at a nominal cost, will unquestionably have missed an exceptional opportunity of furthering the art and science of forestry in Britain.

PRELIMINARY OBSERVATIONS ON THE INFLUENCE OF SITE CONDITIONS ON NATURAL REGENERATION, WITH SPECIAL REFERENCE TO DUNECHT ESTATE, ABERDEENSHIRE

By W. M. McNEILL, M.B.E.

(*Forestry Department, University of Aberdeen*)

DUNECHT Estate provides a number of interesting problems regarding the presence and absence of natural regeneration of tree species. This study was undertaken to obtain factual data concerning self-sown seedlings in differing site conditions in order to discover what correlations might be established between the conditions and the regeneration, and to see, if possible, along what lines silvicultural practice might be directed in the future to achieve the natural regeneration of desired species or to encourage any present trend towards self-establishment.

DESCRIPTION OF THE LOCALITY

Situation. Dunecht Estate is situated about 12 miles due west of the city of Aberdeen in the undulating agricultural district between the foothills of the Cairngorms and the sea. The general elevation is between 300 and 650 feet, but the woodlands concerned in these investigations lie between the 300- and 450-foot contours.

Climate. No rainfall figures for the estate are available, but observations recorded at Aberdeen since 1881 show that the average annual rainfall is 29½ inches, distributed very evenly throughout the year. Over the past 50 years the mean annual temperature has varied between 48·1° F. and 44·2° F., with a maximum monthly average of 62·2° F. (July), and a minimum monthly average of 35·0° F. (January). There are, on the average, 84 days of ground frost each year, mostly occurring between November and March, but only one month (August) has been consistently free of ground frost over the last 20 years. Heavy falls of snow are common. The prevailing winds are from the south (20 per cent.), south-east (10 per cent.), and south-west (15 per cent.), but winds from the north-west (16 per cent.) and west (13 per cent.) are frequent.

THE ESTATE WOODLANDS

Policy Woods and Coniferous Plantations. The wooded portions of the estate fall into two well-defined classes, viz. pure stands of even-aged conifers and mixed stands of coniferous and broad-leaved species. The former occupy the more outlying portions of the estate, while the latter constitute the Policy Woods around Dunecht House. It is principally with the Policy Woods, which cover an area of about 250 acres, that this study is concerned. All the present woodlands

have been artificially established. No remnants of the original natural forest communities remain in the locality, but there is reason to believe that the natural forest was of the oak-birch-pine association, probably near its limit. Historical records refer to the predominance of broad-leaved species in natural or semi-natural woodland in the parish 150 years ago. The present coniferous plantations are of all ages and in many cases the present crop is on a previously planted and felled over site. The commonest species planted is Scots pine. The Policy Woods on the whole are about 100 years old, the youngest 70 years and the oldest 135 years. The present mixture of species varies very considerably; enumerations throughout the Policies show the principal species occurring in the following percentage frequencies: Scots pine 64·2 per cent., Larch 18 per cent., Spruce 5·9 per cent., Birch 3·1 per cent., Beech 2·8 per cent., Douglas fir 2·6 per cent., Oak 1·9 per cent., Rowan 0·2 per cent., other species 1·3 per cent. The woods are for the most part fairly open and usually contain about 50 trees to the acre.

History of Estate Afforestation. There is little available information about the original planting of the Policy Woods. The earliest known record of planting on the estate is a reference in 1792 to '150 acres of hill ground' (traced as within the present Policies) already at that date planted 'with different kinds of trees such as Scotch fir, pine, larix, oak, beech, mountain ash, etc.' A second account of the parish written in 1842 states: 'There were 144 acres under wood in the estate of Echt in the end of last century. Since the beginning of the century the late and present proprietors have planted from 1,500 to 2,000 acres, consisting of the following kinds of trees, viz. Scotch fir, larch, spruce, oak, ash, elm, beech, alder, birch, plane, lime, maple, horse chestnut and Spanish chestnut.' All the historical evidence suggests that the present woodlands were waste land or heather-covered hills before they were planted. An interesting feature of the Policy Woods is the ridging which was, in all probability, done immediately prior to the planting of the present woods. These ridges are still easily seen; they are remarkably regular in spacing, with about 22 feet between each, running usually in the same direction as the slope of the ground and giving the surface a gently corrugated appearance like waves (see Plate I, fig. 1). No specific record can be traced of this very considerable operation which must have involved great labour, but there is historical reference to large-scale improvement measures carried out in the locality about the time that the present woods were planted. This extensive ridge planting caused marked interference with the original soil profiles, and there is ample evidence from the soil pits dug in connexion with this study to show a previous surface layer now some distance below the present surface. Plate I, fig. 2, shows, in the centre, a cross-section of one of these ridges.

Soil and Surface Vegetation. The soils are typical of this part of Aberdeenshire. The underlying rock is granite, and the whole area is overlaid with varying depths of glacial and fluvio-glacial deposits of boulder clay, gravels, and gritty granitic till. As might be expected, there is considerable variation in detail in the soil types within short distances. A soil and vegetation survey of about 800 acres of the woodlands differentiates eight main soil types, viz. mature podzol, immature podzol, gleyed podzol, disturbed podzol, peaty podzol, brown earth, gleyed

colluvium, and old agricultural soil. The soils of the Policy Woods generally show little obvious signs of leaching, but, as already mentioned, they have been considerably disturbed. The most obvious and best developed podzols are found in the older coniferous plantations. The surface vegetation follows fairly regularly the soil type. Throughout the area five main vegetation types occur, viz. *Calluna* heath, grass heath, moist heath, grass, and herb-bracken. In the Policies the grass or grass heath types are much the most common. In the examination of conditions where natural regeneration of tree species occurs both the soil and surface vegetation are described.

Animals and Birds. The Policy Woods are used as cover for game. Pheasants are reared and are plentiful, hare are common, but rabbits are kept well in control and normally are present in small numbers. Deer very rarely are seen in the woods. The red squirrel is common. Wood pigeon are plentiful. The Policy Woods are also used for grazing for sheep and for winter shelter. The sheep are in the woods chiefly in the spring and autumn and frequent those portions of the woods with a grass vegetation.

OCCURRENCE OF NATURAL REGENERATION

Throughout the Policy Woods regeneration of tree species is almost entirely absent or occurs only sparsely or in isolated small patches except in one notable portion. In this particular case an area of about 13 acres near the present Dunecht House was fenced 27 years ago with a strong permanent stock and rabbit-proof fence on three sides, the open side abutting on the gardens of the house. The fenced portion lies within a larger wooded area and the fence does not follow the outside boundary of the wood. The intention at the time was to make this fenced area into a woodland garden, and in one portion of it flowering shrubs and decorative trees were planted. The area within the fence is now well stocked with natural tree seedlings which have originated from seed from mother trees in the enclosed area and from others outside the fence. During the period of complete protection against all browsing animals large numbers of beech, Silver fir, and Douglas fir have established themselves, while spruce, larch, Scots pine, sycamore, maple, ash, birch, and rowan are also found. The contrast between the fenced wood and the woods immediately adjoining, which are similar in stocking, age, and condition, is most marked, for not only is there almost complete absence of any tree regeneration immediately outside the fence, but the ground vegetation is entirely different, see Plate II, fig. 2. A portion of this fenced area was examined in detail and is described later. Apart from this marked exception, regeneration when found in other parts of the Policy Woods is confined almost entirely to beech, Scots pine, Norway spruce, and Silver fir. As already mentioned, any such regeneration in areas subjected to grazing and browsing is found usually in comparatively small patches or groups, especially where the ground vegetation is predominantly of the heath type; for example, small patches of Scots pine regeneration occur both in the Policy Woods and on the edge of older stands in the coniferous plantations; while Norway spruce regeneration, along with beech, is found in some portions of the woods.

These groups of regeneration indicate conditions where, for some reason, the tree species are able to hold their own with other competitors. The questions which naturally arise are, why is regeneration of a particular species found in some places and not in others, and how could an increase in the regeneration of any of the species be induced or encouraged?

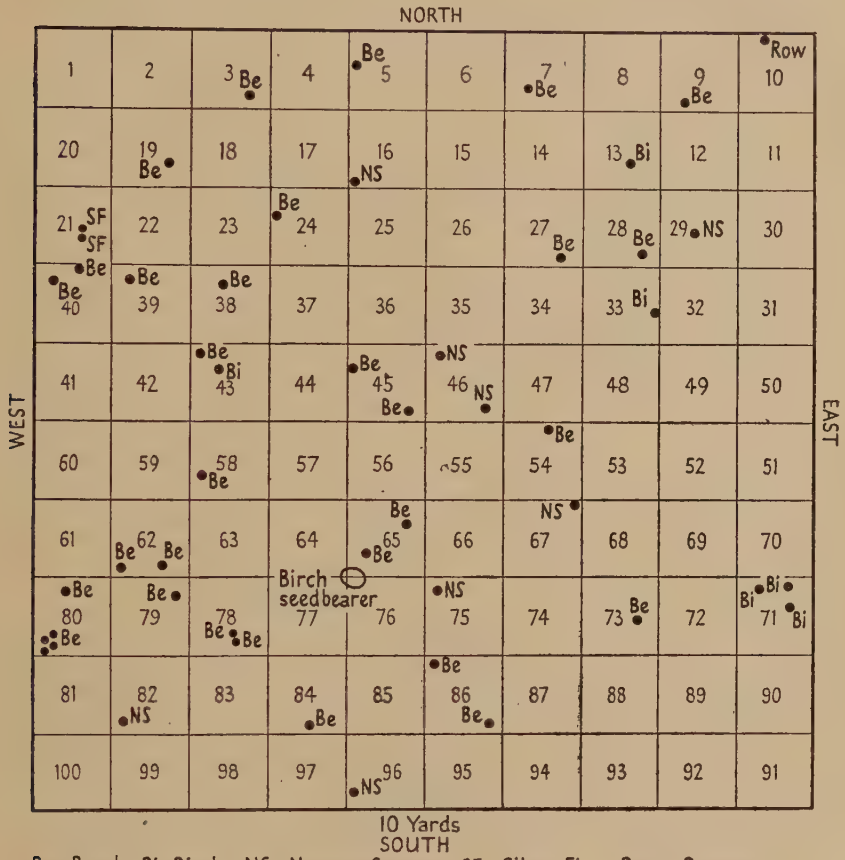
METHODS OF STUDY

Selection of Areas. In order to obtain some information about the conditions where regeneration had already established itself a number of plots were laid out and data recorded regarding the number, size, and distribution of the natural tree seedlings, the source of seed, the surface vegetation, and the nature of the soil. In the fenced area already mentioned a portion of 3 acres was selected where there had been no planting of ornamental shrubs and where, as far as could be ascertained, there had been no interference since the area was enclosed. A plot of this size was chosen so that knowledge could be obtained regarding the range of regeneration from sources of seed. In addition 5 plots, each 10 yards square, were laid out in different parts of the estate as much as 2 miles apart where patches of natural regeneration occur. One of these plots records data concerning Norway spruce, while the other four are in Scots pine regeneration.

Fenced Area. The plot surveyed in this area is a parallelogram with two sides, 441 and 300 feet long respectively, formed by the surrounding fence. Three lines were laid out along the longer side at 110, 220, and 330 feet from the angle of the fence. Each of these lines was surveyed parallel to the shorter side of the plot and a strip 3 feet wide laid out on the ground along these three lines. In addition two similar strips were marked out at 100 and 200 feet from the angle of the fence along the shorter side and running parallel to the longer side. In each of these five strips every square yard was separately examined, and all tree seedlings found were measured and their height recorded in inches. Notes were also made of the ground vegetation in each square yard along the two longer strips. Thus altogether 594 square-yard plots were counted for regeneration, and vegetation notes were made for 294. This represents a minute regeneration enumeration of approximately 4 per cent. of the area of the entire plot. A chart was made of the plot and the position of the enumerated strips inserted, as well as the position of all seed-bearers. All seed-bearers were numbered and the girths at breast height recorded. Three soil pits were dug and examined; the positions of these were immediately adjacent to one of the enumerated strips and they were selected with reference to the topography, type of ground vegetation and tree regeneration. The location of each of these pits was also entered in the chart. When regeneration of species not recorded among the enumerated seed-bearers was met with, distances to the nearest source of seed outside the plot were measured. The results of this survey of regeneration are given in the next section.

10-*yard-square plots.* Each of these plots was carefully pegged on the ground with the four sides in all cases orientated to the four cardinal points of the compass. Each square was subdivided into 1-square yard sections and each of

these sections was examined and any regeneration counted, measured, and recorded. A chart was kept for each of these 100-square-yard plots showing the kind and position of all regeneration. Notes were made of the surface vegetation and a soil pit was dug and examined in each plot. Information regarding the



Be = Beech. Bi = Birch. NS = Norway Spruce. SF = Silver Fir. Row = Rowan.

DIAGRAM I

adjacent woodland and the source of seed was also recorded for each plot. The chart and accompanying enumeration data for Plot No. 1 is reproduced in Diagram I and Table III. The data obtained from each plot is given in the next section.

DATA

Fenced Area

Position and Area. Policy Woods. West Belt. 3·03 acres.

Topography. Gentle slope from WSE. to NE. Elevation 450–400 feet.

Ground Vegetation. Varied and complex. Grasses, chiefly *Holcus* spp., common but

rarely such an exclusive covering as outside fence. In many parts grass thin with considerable leaf litter. *Veronica* and *Oxalis* common. Patches of pure *Oxalis* and *Polytrichum* spp. In wetter pockets bramble and few ferns.

Soil Description. No evidence of ridging in any part of the plot.

Pit 1. 15 feet inside W. boundary fence. Very gentle slope to E. Elevation about 450 feet. Beech litter, sparse grass with occasional *Veronica* and *Viola*. Under shade of beech, Silver fir, and European larch seed-bearers.

0–¾ inch. Leaf litter, chiefly beech.

¾–15 inches. Russet-brown loam, porous and crumb structure. Few stones. Roots throughout.

15 inches +. Bright orange-red with grey-blue mottling. Gritty and sticky. Structureless. Impeded drainage. No free water at 30 inches (Aug.). Stones. Large roots. Slight compacting (¼ inch), bright rust colour at upper limit.

Pit 2. 185 feet from W. boundary fence. Gentle slope to E. Elevation about 425 feet. Grasses (*Holcus* spp.) abundant. *Polytrichum* spp. occasional. *Rubus Idaeus* infrequent.

0–¾ inch. Undecomposed leaves and moss with grass roots.

3–15 inches. Blackish-brown merging to orange-brown loam, porous, crumb structure. Roots and earthworms throughout.

15 inches +. Yellowish-grey till with russet mottling. Compact. Coarse gritty. Few roots. No worms. Russet crust (¾ inch) at upper limit of layer. No free water at 20 inches (Aug.).

Pit 3. 220 feet from W. boundary fence. Slight slope to NE. Wet. Elevation about 400 feet. Grasses, *Rubus Idaeus*, *Oxalis*, *Ranunculus*, *Dryopteris*.

0–6 inches. Dark grey loamy clay. Very wet. Roots. No stones.

0–10 inches. Yellowish-grey loam. Very wet. Roots. No stones.

10–12 inches. Dark grey gritty loam. Very wet. Few roots.

12 inches +. Light yellow-grey coarse grit. Water table at 9 inches (Aug.).

Overwood and Natural Regeneration. All trees bearing or old enough to bear seed included in enumeration of seed-bearers. Density of seed-bearers varies over area with closer stocking in the northern two-thirds of plot. Average stocking represents 55 trees per acre. Species comprising seed-bearers fairly evenly distributed except beech, which is mostly confined to the W. edge of plot. Regeneration unequal, distribution on 594 square-yard sub-plots given in Table I:

TABLE I

Sq. yd. sub-plots with	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16 seedlings
Number	301	107	42	39	24	21	15	14	8	5	5	4	2	4	1	1	1

Greatest distance along an enumerated strip with no recorded seedlings: 87 feet (29 sq. yds.) in most easterly strip. Largest number of seedlings of any single species in one square yard: beech 13 and Silver fir 11. Regeneration most concentrated within definite distances from seed-bearers resulting in more profuse regeneration in western and northern than in eastern and southern portions. Very little beech or Silver fir regeneration outside a range of 50 feet from source of seed. Observed maximum distance of regeneration from nearest seed source: Silver fir 90 feet, beech 85 feet, Douglas fir 70 feet, maple 131 feet, ash 158 feet. Regeneration of all species markedly less where ground vegetation composed chiefly of grass, patches of *Polytrichum*, or near stems of seed-bearers. Summary of data, expressed per acre, given in Table II:

TABLE II

Seed-bearers per acre				Natural regeneration per acre			
Species	*Number*	*Frequency per cent.*	*Mean girth b.b.o.b.* (in.)	*Number*	*Frequency per cent.*	*Range of ht.* (in.)	*Mean ht.* (in.)
Scots pine	11·5(12)	20·9	70	24	0·3	14–142	60·0
Douglas fir	9·2(9)	16·8	70	155	1·9	1–127	49·0
Beech	7·6(8)	13·8	67	2,673	32·1	1–174	12·1
*Silver fir	5·6(6)	10·2	94	4,196	50·4	1–78	6·8
Oak	5·6(6)	10·2	51	8	0·1	6	6·0
European larch	4·9(5)	8·9	70	..	..	..	..
Norway spruce	2·9(3)	5·4	83	8	0·1	13	13·0
Birch	2·6(3)	4·8	31	350	4·2	7–170	66·0
Sweet chestnut	2·3(2)	4·2	70	..	..	..	..
†Pinus strobus	1·0(1)	1·8	64	..	..	..	..
White beam	0·7(1)	1·2	18	..	..	..	..
Sycamore	0·7(1)	1·2	39	310	3·7	2–39	5·3
Lime	0·3(0)	0·6	45	..	..	..	..
Norway maple	..	..	..	424	5·1	1–12	3·3
Rowan	..	..	..	111	1·4	1–192	43·0
Ash	..	..	..	49	0·6	3–41	11·3
Holly	..	..	..	8	0·1	23	23·0
Total	54·9(55)	..	..	8,316	..	..	..

* *Abies pectinata.* † 1 tree with 3 separate stems.

Observations

1. The numbers of naturally regenerated seedlings counted represents a total of 8,316 seedlings per acre, ranging in height from 1 inch to 192 inches but for the most part around 10 inches.

2. Regeneration has been proceeding for a number of years as shown by the range of heights. Regeneration was probably first established soon after the fencing of the area. The largest seedlings now are the more light-demanding species, e.g. Scots pine, birch, rowan, and Douglas fir. Regeneration is still proceeding, especially in the case of shade-bearing species, e.g. Silver fir and beech, as shown by the number of seedlings one or a few inches high.

3. The indication that regeneration is more profuse and at farther distances from sources of supply in east and north-east direction is probably due to the prevailing winds being from west and south-west and to the slope of the ground to east.

4. Regeneration differs in species and frequency from the seed-bearers, e.g. Scots pine represents 20·9 per cent. of the seed-bearers with only 3 seedlings counted or 0·3 per cent. of the total regeneration. Silver fir representing 10·2 per cent. of seed-bearers is present to the extent of over 50 per cent. of the regeneration, no larch seedlings were counted although this species makes up 8·9 per cent. of the seed-bearers.

5. Certain species represented in the regeneration are totally absent from the

seed-bearers in the plot; a notable example is maple, which represents over 5 per cent. of the total regeneration counted. The nearest maple seed-bearers are situated outside the fence to the west of the plot.

6. Regeneration in all directions outside the fenced area is practically non-existent. Surface vegetation outside the fence is predominantly grass although the overwood conditions are similar to those within the plot.

100-square-yard Plots

PLOT No. 1

Position and Area. Policy Woods. Heather Hill. 100 square yards.

Topography. Slight slope towards N. Elevation about 420 feet.

Adjacent Woodland. Plot situated within wood composed principally of Scots pine and Norway spruce, about 70 years old, with scattered hardwoods, principally beech. Enumeration of all trees with girth of 12 inches or over within 1 chain from centre of plot as follows:

Species	*Girth b.h.o.b.* (in.)	*No.*
Norway spruce. . .	76, 70, 51, 46, 42, 38, 37, 32, 28, 21, 21, 19, 15, 13, 12	15
Scots pine . . .	63, 61, 61, 56, 53, 50, 48, 36	8
Birch	48, 46, 30	3
European larch . .	89	1
	Total	27

Average total height of dominant spruce: 76 feet. A few beech seed-bearers occur in the vicinity, the nearest being 70 feet from centre of plot. The edge of the wood is 150 feet to E. of plot, and beyond the wood for some distance in this direction is open heath.

Light conditions within plot. Except for shade of one birch (girth 48 inches) near the centre of plot, overhead light uninterrupted. Lateral shade cast by surrounding wood in all directions.

Ground Vegetation. Calluna vulgaris: abundant, dominant. *Vaccinium Myrtillus*: abundant, co-dominant. *Hypnum* spp.: abundant. *Plagiothecium undulatum*: abundant. *Polytrichum* spp.: abundant. *Empetrum nigrum*: occasional. *Luzula* spp.: infrequent. Heather about 22 inches high and clumps fairly open.

Soil Description. 0–2 inches. Undecomposed heather and moss litter with beech and birch leaves.

2–6 inches. Chocolate-brown humus. No mineral particles.

6–8 inches. Dark, black, well-differentiated layer. Humus with mineral material. Medium-sized stones. Roots throughout.

8–9 inches. Light grey, fairly well defined. Finely gritty single-grained structure. Stony. Roots.

9–12 inches. Bright orange-brown with much irregular black humus staining. Boundary merging with last. Loamy, tendency to crumb. Particles fine. Roots.

12–15 inches. Very dark brown to black. Irregular boundary. Black patches structureless humus with very little mineral material. Stones. Roots throughout. (Previous humus surface layer?)

15–22 inches. Russet-brown, merging, darker above, paler below. Gritty loam, tendency to crumb, stones. Roots throughout. Free drainage.

22 inches +. Yellow ochre, hard compacted very gritty till. Individual particles coarse and angular. Rotting stones (granite). Boundary well defined. No roots. No free water at 26 inches (Aug./Sept.).

Whole area, including plot, previously ridged.

Natural Regeneration. For details see Fig. 1 and Table III. Analysis of regeneration counts:

Species	No.	Frequency (per cent.)	Range of height (in.)	Mean height (in.)
Beech	33	66	3–10	4·4
Norway spruce	8	16	16–288	77·1
Birch	6	12	10–26	15·3
Silver fir	2	4	1–2	1·5
Rowan	1	2	17	17·0
Total	50			

TABLE III. *Regeneration Counts Plot No.* 1

Square no.	Species and height (in.)	Square no.	Species and height (in.)	Square no.	Species and height (in.)	Square no.	Species and height (in.)
1	..	26	..	51	..	76	..
2	..	27	Be 4	52	..	77	..
3	Be 4	28	Be 6	53	..	78	Be 4, 5
4	..	29	NS 36	54	Be 3	79	Be 4
5	Be 8	30	..	55	..	80	Be 3, 3, 3, 4, 4
6	..	31	..	56	..	81	..
7	Be 3	32	..	57	..	82	NS 96
8	..	33	Bi 11	58	Be 4	83	..
9	Be 9	34	..	59	..	84	Be 3
10	Row 17	35	..	60	..	85	..
11	..	36	..	61	..	86	Be 3, 6
12	..	37	..	62	Be 3, 4	87	..
13	Bi 20	38	Be 2	63	..	88	..
14	..	39	Be 9	64	..	89	..
15	..	40	Be 3, 4	65	Be 3, 4	90	..
16	NS 288	41	..	66	..	91	..
17	..	42	..	67	NS 75	92	..
18	..	43	Be 3, Bi 26	68	..	93	..
19	Be 3	44	..	69	..	94	..
20	..	45	Be 4, 10	70	..	95	..
21	SF 1, 2	46	NS 35, 49	71	Bi 10, 11, 14	96	NS 16
22	..	47	..	72	..	97	..
23	..	48	..	73	Be 3	98	..
24	Be 6	49	..	74	..	99	..
25	..	50	..	75	NS 22	100	..

Observations. Natural regeneration of spruce has been going on slowly for a number of years. Regeneration of this species is found in small numbers widely distributed through the adjacent wood, especially where gaps in the canopy occur. No Scots pine regeneration was observed anywhere in the wood except on the exposed west boundary and there very occasionally. Apart from inadequate light, conditions appear too mesophytic for Scots pine regeneration. The high percentage of beech regeneration is not evident until minute examination is made. The soil profile suggests conditions favouring grasses in competition with tree species. There is evidence of considerable browsing, hare and rabbits are

not uncommon and the area is grazed by sheep. The indications are that considerably more regeneration would result from complete exclusion of all browsing animals. Conditions for increased regeneration of spruce might be made more favourable by judicious exposure of the soil and control of light conditions. Grasses are absent from the surface vegetation within the plot, but *Deschampsia flexuosa* is present throughout the wood and is likely to spread with the opening of the canopy.

PLOT NO. 2

Position and Area. W. edge of Policy Woods near main drive from Dunecht Lodge. 100 sq. yds.

Topography. Practically flat with very gentle slope to W. Open drain few yards to W. of plot with lower-lying open ground beyond. To E. gently rising wooded land. Elevation about 325 feet.

Adjacent Woodland. Stocking in immediate vicinity of plot very open, consists of Scots pine, but other species, such as beech, Silver fir, and Norway spruce occur at little distance inside wood. Enumeration of all trees within 1 chain from centre of plot as follows:

Species	*Girth b.b. o.b. (in.)*	*No.*
Scots pine . . .	101, 101, 86, 85, 80, 77, 67, 65	8

Average total height of Scots pine, 86 feet.

Light Conditions within Plot. There are no seed-bearers within plot. The Scots pine mother trees are arranged close to and fairly evenly around plot, but cast little overhead shade. Light uninterrupted to W.

Ground Vegetation. Calluna vulgaris: abundant, dominant. *Betula verrucosa*: frequent. *Hypnum* spp.: infrequent. *Polytrichum* spp.: infrequent. *Blechnum spicant*: infrequent. *Juncus* spp.: infrequent. *Viola Riviniana*: occasional. *Potentilla erecta*: frequent-occasional. Grasses: occasional. *Vaccinium Myrtillus*: locally common.

The ground vegetation of the plot represents part of an isolated patch with rather open heather 15–20 inches high as a dominant component. A short distance away vegetation is chiefly grasses and no regeneration found. The Scots pine regeneration follows closely the line of the heather. Birch seedlings, never higher than the heather, so frequent throughout plot that included as part of ground vegetation and not counted. Large inhabited rabbit burrow found in square 39 of plot. Birch appeared heavily browsed but Scots pine seedlings showed no sign of recent injury.

Soil Description 0–2 inches. Moss litter.

2–6 inches. Light grey-brown with definite darkening at lower boundary. Pale and dark streaks horizontally throughout. Fine sand. Structureless. No stones. Roots throughout. Earthworms.

6–9 inches. Light pinkish-grey, gritty sand. Structureless. Roots.

9–10 inches. Dark black-brown humus without mineral particles.

10–10¾ inches. Grey to violet-grey, very fine sand with some humus. Structureless. Unimpeded drainage. Roots.

10¾ inches +. Pinkish-brown to greyish-yellow pure sand. Fine particles. No stones. Roots to 21 inches. Worms at 24 inches. Free drainage. No free water at 30 inches (Aug./Sept.).

In the course of an extensive soil survey of the estate woodland no other soil profile was found similar to this one. The sand is water deposited, and the general configuration of

the ground suggests that the plot is situated on the rim or edge of a previous natural lake. Similar vegetation with Scots pine regeneration not far distant appears to indicate another portion of this rim.

The marked humus layer at 9 inches from present surface appears to represent the original ground-level. The particularly freely drained nature of the soil is an exception to most other profiles examined.

Natural Regeneration. Analysis of regeneration counts:

Species	*No.*	*Frequency (per cent.)*	*Range of height (in.)*	*Mean height (in.)*
Scots pine	78	95·1	3–40	24·8
Hazel	2	2·4	17	17·0
Norway spruce	1	1·2	17	17·0
Rowan	1	1·2	12	12·0
Total	82			

Observations. The regeneration is almost entirely Scots pine, although seed-bearers of other species are well within range of the plot. The Scots pine has established itself successfully in spite of the presence of rabbits on the spot. Most of the regeneration is between 20 and 30 inches, suggesting establishment within a short period; very few seedlings of recent origin were observed. The correlation between soil, surface vegetation, and tree regeneration is very marked. Several yards away where the soil is of the general brown podzolized type (see Plot No. 1) the heather is replaced by grasses and mosses and tree regeneration is almost completely absent. The well-drained, comparatively dry, sandy conditions, open light conditions, and absence of lateral shade to the west all favour natural regeneration of the Scots pine.

Plot No. 3

Position and Area. Near former saw-mill site. Braigiewell. 100 sq. yds.

Topography. Sloping gently to SW. Elevation 327 feet.

Adjacent Woodland. Braigiewell plantation consisting of a pure stand of Scots pine 60–70 years old situated 135 feet to NW.

Light Conditions within Plot. Open light conditions with shelter but no shade from adjacent plantation.

Ground Vegetation. Calluna vulgaris: abundant, dominant. Mosses: abundant. *Potentilla erecta*: occasional. *Empetrum nigrum*: occasional. *Vaccinium Myrtillus*: infrequent.

The area where plot is situated is shown as woodland on the Ordnance Survey map dated 1899. Date of felling uncertain. Area adjacent to plot contains a very few scattered stunted Scots pine seed-bearers with considerable groups of broom. Agricultural land immediately to SE.

Soil Description. 0–2½ inches. Close sod composed of heather and moss and parting easily at junction with mineral soil.

2½–3½ inches. Grey gritty sand. Coarse particles.

3½–5½ inches. Dark chocolate-brown. Humus stained throughout. Peaty grit. Structureless. Roots.

5½–18½ inches. Russet-brown with darker mottling in irregular patches. Much humus. Gritty loam, tendency to crumb. Some small stones. Roots throughout.

18½ inches +. Yellow-fawn, coarsely gritty till. Small stones frequent. Free drainage. No roots. No free water at 23 inches (Sept.).

Adjoining the plot to NE. is site of previous saw-mill which was in operation in 1936. Temporary living quarters of saw-mill workers said to have been close to position of plot.

Natural Regeneration. Analysis of regeneration counts:

Species	*No.*	*Frequency (per cent.)*	*Range of height (in.)*	*Mean height (in.)*
Scots pine	24	100	5–35	19·5

Observations. Regeneration is very sparse. The presence of all sizes of seedlings suggests very slow but continuous establishment over a number of years. No species other than Scots pine is represented. The prevailing winds would not assist dissemination of seed. The close nature of the surface sod and the aspect are both unfavourable to regeneration.

Plot No. 4

Position and Area. SW. boundary of Braigiewell plantation. 100 sq. yds.

Topography. Practically flat. Elevation about 350 feet.

Adjacent Woodland. Braigiewell plantation, consisting of a fully stocked pure stand of Scots pine 60–70 years old, is situated on three sides to NW., E., and SE. and 123 feet from plot at nearest point.

Light Conditions within Plot. Plot situated in an open area of about 4½ acres with no shade from surrounding wood. Agricultural land to SW.

Ground Vegetation. Calluna vulgaris: abundant, dominant. *Vaccinium Myrtillus*: frequent. *Empetrum nigrum*: occasional. *Deschampsia flexuosa*: occasional. *Luzula* spp.: infrequent.

The area was previously wooded, large stumps are still traceable. Past history of irregularly shaped bare area where plot situated not known, but apparently it was originally planted as part of adjoining Braigiewell Wood and probably met with some accident. The present state of the heather, which is obviously old and in large clumps which are opening out, suggests that the area has been without trees for over 60 years. Interspersed with the heath type found in plot are large patches of almost pure *Deschampsia flexuosa* in which Scots pine regeneration is very scarce.

Soil Description. 0–3½ inches. Loose raw humus and roots, chiefly heather.

3½–10 inches. Dark chocolate to black. Peat with mineral particles in lower half. Slight suggestion of lighter-coloured layer at junction with mineral soil. Roots throughout.

10 inches +. Bright orange-yellow with humus staining in patches. Loam. Slight tendency to crumb. Many medium-sized stones. Unimpeded roots throughout. No free water at 26 inches (Sept.).

Natural Regeneration. Analysis of regeneration counts:

Species	*No.*	*Frequency (per cent.)*	*Range of height (in.)*	*Mean height (in.)*
Scots pine	12	75	6–77	24·7
Rowan	3	18·75	40–68	53·3
Birch	1	6·25	52	52·0
Total	16			

Observations. Although light conditions, aspect, and seed supply are all favourable for regeneration of Scots pine, results show only very partial establishment and a very slow rate of successful regeneration. There is a deeper layer of peat in

the soil of this plot than in any other examined. There is a considerable amount of grass as well as *Vaccinium* among the heather. The underlying soil is not particularly porous. Competition of the surface vegetation is unfavourable to tree species. This site is probably too mesophytic for profuse natural regeneration of Scots pine. The tendency towards establishment of this species might be encouraged by operations aimed at creating drier soil conditions and the exposure of the mineral soil.

Plot No. 5

Position and Area. Adjoining main drive from Estate Lodge near Loch of Skene. 100 sq. yds.

Topography. Sloping from edge of drive to NE. with free drainage. Elevation about 300 feet.

Adjacent Woodland. Adjacent area previously wooded chiefly with Scots pine. Woods very severely damaged by wind and all but a few single trees and groups of trees thrown and subsequently removed about 40 years ago. Since then there has been some planting, chiefly of decorative trees, mostly Silver firs, near the carriageway. Scattered remnants of original wood remain sufficiently near to provide ample seed supply. The nearest Scots pine seed-bearers are 50 feet from plot.

Enumeration of trees within 1 chain of centre of plot as follows:

Species	*Girth b.h. o.b. (in.)*	*No.*
Scots pine	59, 54, 51	3
Norway spruce	56	1
	Total	4

Light Conditions within Plot. Overhead light uninterrupted. Little lateral shade cast by surrounding trees. Plot well sheltered.

Ground Vegetation. Calluna vulgaris: abundant, dominant. *Vaccinium Myrtillus*: common. *V. vitis Idaea*: common. Mosses: frequent. *Deschampsia flexuosa*: occasional. *Empetrum* nigrum: infrequent.

A relatively dry heath type. The heather is very open and about 24 inches high.

Soil Description. 0–1½ inches. Moss and heather litter.

1½–4 inches. Chocolate brown peat. No mineral particles, rather dry.

4 inches +. Russet brown with humus staining. Loose river gravel. Many smooth rounded stones. Roots throughout. Very free drainage. No free water at 26 inches (Sept.).

Plot situated on bank of river gravel with particularly free drainage to NE. Very little appearance of podzolization.

Natural Regeneration. Analysis of regeneration counts:

Species	*No.*	*Frequency (per cent.)*	*Range of height (in.)*	*Mean height (in.)*
Scots pine	26	92·9	13–186	53·5
Rowan	2	7·1	6–8	7·0
Total	28			

Observations. Regeneration in the plot is not so dense as in some small groups in the vicinity. Regeneration is most marked at the edge of the drive and on the

bare sandy gravel of the drive itself. Nowhere are open gaps along the drive large, but where these occur and Scots pine seed-bearers are present nearby, plentiful regeneration has established itself. Although other seed-bearers are present regeneration is almost exclusively of Scots pine. This is evidence of considerable browsing. Regeneration is noticeably better on the north-east side of the drive. The site is particularly well drained. There is not much grass in the surface vegetation.

CONCLUSIONS.

1. On Dunecht Estate natural regeneration of tree species is never profuse, except where all browsing animals have been totally excluded for a considerable period of time.

2. Following protection against animals, natural regeneration of broad-leaved trees and conifers occurs freely, especially in the case of beech and Silver fir.

3. The exclusion of grazing animals has a marked effect on the ground vegetation; in particular the quantity and vigour of the grasses diminishes. Continual grazing by sheep appears to encourage the growth of grass; it may be partly by manuring.

4. Data collected suggest that, in the climatic conditions obtaining, the unfenced portions of the Policy Woods would regenerate themselves freely if all browsing animals were excluded, provided the percentage of broad-leaved trees to conifers is not less than 25 per cent., and provided the seed-bearers contain at least 15 per cent. beech and 10 per cent. Silver fir.

5. In predominantly coniferous stands with a heath or grass heath surface vegetation there is no evidence to show that complete exclusion of animals alone would result in a crop of coniferous regeneration, although there are indications that it would substantially increase the chances of survival.

6. In no part of the estate are conditions at present very favourable for the natural regeneration of spruce or Scots pine, but the presence of regeneration of these species suggests that in some cases at least conditions could be made more favourable.

7. In the case of Scots pine the most favourable conditions are a sandy or gravel soil, dry conditions, and full or almost full light.

8. Norway spruce will regenerate in *Calluna-Vaccinium* surface vegetation, provided lateral shade is adequate and soil moisture sufficient.

9. The proximity of seed-bearers and their position in relation to the prevailing winds at seedfall and to the topography is important.

10. In the case of all conifers the presence of grasses in the surface vegetation lessens the chance of establishment.

11. Where heather is the dominant component of the surface vegetation there is little Scots pine regeneration until the heather clumps have reached a fair age and open out from the centre.

12. There is no local evidence of marked periodicity in the seed supply of conifers affecting natural regeneration. No data have so far been obtained regarding the amount of seed produced by any species annually.

FIG. 1. Policy woods, showing ridging

FIG. 2. Policy woods, soil profile showing section through ridge (centre)

PLATE I

FIG. 1. Area fenced against browsing, showing contrast in ground vegetation

FIG. 2. Natural regeneration of beech and silver fir within area fenced against browsing

PLATE II

13. Further factual data are required regarding light intensities where regeneration occurs in partial shade and also regarding the ages of recorded seedlings.

ACKNOWLEDGEMENTS.

The thanks of the writer are expressed to Lord Cowdray for the facilities for study on Dunecht Estate, to Professor Steven for help and advice, to Mr. C. Y. Ross, head forester, on Dunecht Estate, for information given and interest taken, and to Messrs. J. F. Goodwin and I. A. R. B. Marshall, forestry students, for assistance with the field investigations.

ESTABLISHMENT OF OAK PLANTATIONS IN EAST ANGLIA

By G. D. ROUSE

(*Forestry Commission*)

PROMINENT continental foresters, when inspecting the large tracts of conifer forests in East Anglia, have expressed the opinion that the better soil sites are suitable for the growth of oak; it has been difficult to convince them that it is not the soil but climatic conditions which prove to be the limiting factor in the establishment of this species. The soils themselves are by no means good; on the main blocks of Thetford Chase the soil is sand with flints overlying chalk. The sand varies in depth from a few inches—and of this type there are several hundreds of acres—to pockets where it is several feet deep. On the fringes of the Breckland the soil improves: on the southern boundary in the King's Forest the sand is replaced by a light sandy loam, though the chalk is still very near the surface. On the eastern boundary this improvement in quality is combined with a general increase in depth; and in the north-east, as at Hockham, the sand merges into a strong clay loam. In Rendlesham Forest, straddling the road from Woodbridge to Orford in East Suffolk, the soil conditions are better, a light sand loam of fair depth overlying Chillesford Crag.

The chief climatic conditions which adversely affect oak, especially in its young stages, are the late spring and early autumn frosts, the prolonged summer droughts, and the drying east winds in the spring. The mean temperatures for the Breckland locality do not show any outstanding deviations from the normal, though there is a tendency towards extremes in the maxima and minima as compared with the country as a whole. The mean figures for the readings recorded at the meteorological station on Thetford Chase for the three years 1941–3 are given below.

TABLE I

Month	*Mean screen temperature in*		
	Max.	*Mean*	*Min.*
Jan.	39·5	33·4	27·3
Feb.	42·2	36·0	29·9
Mar.	49·9	39·6	29·2
Apr.	56·2	46·0	35·9
May	61·5	49·7	37·9
June	68·0	56·4	44·9
July	72·4	60·8	49·3
Aug.	71·1	60·3	49·4
Sept.	68 0	57·0	46·0
Oct.	60·0	51·0	41·9
Nov.	48·7	41·0	33·3
Dec.	45·4	39·1	32·8

The distribution of night ground frosts throughout the year gives more indication of the abnormalities of the temperature, and Table II gives the average monthly number of nights when ground frosts were recorded for the three years 1941–3.

TABLE II

Month	*No. of nights of ground frost*
Jan.	20
Feb.	20
Mar.	18
Apr.	16
May	11
June	2
July	..
Aug.	..
Sept.	4
Oct.	9
Nov.	16
Dec.	19

TABLE III

Date (1944)	*Minimum temperature, ° F.*	
	Screen	*Grass*
4 May	24	17
7 „	25	21
8 „	22	17
9 „	31	24
15 „	25	17
19 „	30	27
20 „	30	27
6 June	41	30
8 „	41	27
11 „	35	29
15 „	38	30
24 „	30	24
14 Aug.	40	32
15 „	41	31
10 Sept.	29	27
11 „	30	26
12 „	30	26
17 „	37	32
28 „	34	30

The 1944 data are given in Table III. The frost of 24 June was so severe—coming at a time when, for the previous month, the mean daily maximum temperatures had been 66° F.—that in low-lying places all oak foliage within 20 feet of ground level was blackened. There was in addition one night of ground frost in July 1942.

The high numbers of ground frosts during the dormant months are of little

significance in so far as the growth of oak is concerned, but any of the frosts in May or June may have devastating effects, whilst those of September are liable to cut back the still tender lammas shoots of the smallest trees.

Frost conditions at Rendlesham are somewhat modified by proximity to the coast, but nevertheless ground frosts in June are of regular occurrence.

The rainfall for the district is low, averaging 24·00 inches for 1941–4, and this, coupled with the low moisture retentivity of the sandy soil, means that lack of moisture can be a limiting factor for growth. That the rainfall is fairly evenly distributed throughout the season, with a drier tendency in spring and early summer, is shown in Table IV, the average monthly rainfall for the years 1941–3 at Thetford Chase and Rendlesham.

TABLE IV

Month	*Rainfall in inches*	
	Thetford	*Rendlesham*
Jan.	2·96	2·60
Feb.	1·87	1·20
Mar.	1·95	2·29
Apr.	1·16	1·52
May	1·40	1·72
June	1·98	1·38
July	2·14	2·40
Aug.	2·44	2·46
Sept.	1·69	1·43
Oct.	2·26	3·25
Nov.	2·26	2·64
Dec.	1·89	1·61
Total	24·00	24·50

It is inevitable, with such a low rainfall, that periods of complete drought should occur with some regularity, and the major periods during the years 1941–3 are summarized in Table V.

TABLE V. *Periods of Complete Drought*

Year	*Duration*	*Dates*
1941	16 days	2–17 May
	20 „	11–30 June
	25 „	14 Sept.–8 Oct.
1942	31 „	9 Apr.–10 May
1943	35 „	17 Feb.–23 Mar.
	16 „	19 June–4 July

In addition periods of a fortnight or more during which the total precipitation does not exceed 0·10 inches are of comparatively frequent occurrence. Individual showers of this magnitude or less must be of negligible benefit to a tree crop since that portion of the moisture which is not evaporated from the leaf surface is dried up, during the warmer months, before it penetrates the surface of the mineral soil.

It will thus be seen that the forester who, whilst fully aware of these local climatological factors, proceeds to plant oak on a large scale must have had considerable experience under such trying conditions or be able to draw on the experience of others.

In the early 1930's the Forestry Commission acquired some land a little better in quality than the average Breckland sand, and it was on this land that a considerable amount of oak planting was done. From the references to Rendlesham Forest in previous paragraphs it will readily be understood that the oak plantations formed there became established quicker than those under the more severe conditions of Thetford Chase; hence the experimental treatment of these plantations was of necessity undertaken at Rendlesham, but the technique evolved there is now proving equally applicable to the Thetford areas.

The silvicultural treatment so far has had to contend with two problems:

1. The establishment of an oak crop with nurses, and
2. The treatment and removal of the nurses to maintain optimum conditions for the Oak.

1. THE ESTABLISHMENT OF THE CROP.

In order to get the oak above the general frost level it was apparent that it would have to be intimately mixed with a frost-resistant species capable of giving adequate protection, and for this purpose Scots pine was selected. The planting method fairly extensively adopted during the period 1930–3 was that of single-furrow ploughing at 4 ft. 6 in. spacing. In each furrow Scots pine were planted at 9 feet staggered with the adjacent row, and between the pines 3 oak were planted in each space 1 ft. 6 in. to 2 feet apart. This layout can be diagrammatically represented thus:

```
      S    o o o    S    o o o    S
S   o o o    S    o o o    S    o o o    S
      S    o o o    S    o o o    S
S   o o o    S    o o o    S    o o o    S
      S    o o o    S    o o o    S
```

S = Scots pine o = Oak

The relatively large number of oak, about 3,000 per acre, might be expected to produce a clean crop.

2. SUBSEQUENT TREATMENT OF THE NURSES.

On the best sites both species got away well, and in parts of Cpt. 33 at Rendlesham II the oak held its own with the Scots pine right from the start without any check. Four years after planting the Scots pine were not needed as nurses, and advantage was taken of a profitable Christmas-tree market to remove them. In the same season the blanks caused by the removal of the pines were filled with beech, and in a further 4 years it was apparent that this species had been introduced many years too soon. The crop was then—1939—in its ninth growing season, and the oak, at 3,000 to the acre had formed a dense thicket

averaging some 7 to 8 feet in height. In these conditions most of the beech were suppressed, but where the thicket was incomplete several beech were pushing strong slender shoots a foot or more above the surrounding oak.

Only a small proportion of the oak grew as well as this, and throughout the rest of the area the pine nurses were necessarily retained until 1939. They were then on the average 12 feet high and putting on a regular 2 feet each year, whilst the oak under varying microclimatological conditions varied from 8 feet down to as many inches. The pine, being widely spaced, were becoming coarse and heavily branched, and it was clear that large-scale treatment would be necessary in a very few years, and as the nature of this treatment had not yet been determined, the four following sample treatments were applied at once:

(*a*) Removal of the pine.
(*b*) Beheading of the pine.
(*c*) Close pruning of the lower pine branches.
(*d*) Slashing back of the upper pine branches.

(*a*) *Removal of the Pine.* This drastic treatment caused severe check during the first growing-season from which the oak did not fully recover for 3 or 4 years.

(*b*) *Beheading of the pine.* This unorthodox treatment had unexpected results. Where the oak were small the pine had to be cut correspondingly low to admit the requisite light, and where only suppressed branches were left, the stumps, not unnaturally died; but where the oak were sufficiently large to justify the leaving of lateral branches still retaining their full vigour, all such branches turned upwards and in one growing-season each terminal shoot developed the habit and vigour of a leading shoot with the result that heavier shade was thrown on the intervening spaces occupied by the oaks than at the bases of the pines.

(*c*) *Close pruning of the lower pine branches.* Since the pine were, at this stage, only about 12 feet high, it was inexpedient to prune too heavily, but by pruning to a height of 3 feet to 4 feet it was possible to remove those laterals which were most nearly meeting over the oak, thus admitting a moderate amount of overhead light.

It only took one year for the next whorl of branches to meet, and it was apparent that such an operation, requiring almost annual repetition, would be too expensive to undertake on a large scale.

(*d*) *Slashing back of the upper pine branches.* This operation was the cheapest of the four, at that time being done on piecework at *7s. 6d.* per acre, and served the purpose of admitting enough light to the oak without impairing the vigour of the pine.

This last method was adopted on a large scale in the ensuing 4 years. It is of interest to record that complaints have been made against the unsightliness of this method culminating, in one instance on Thetford Chase, in close pruning of the live branches comparatively high up the young stem. This resulted in a severe attack of *Pityogenes* which killed many of the trees and rendered the roadside belt considerably more unsightly.

As the oak plantations of the same age on Thetford Chase reached the same

stage of development as those already described at Rendlesham, this same slashing treatment was applied. In the comparatively mild winter of 1943–4 it was noted that oak some 5 feet to 9 feet high which had been opened up stood the winter conditions normally whilst adjacent oak in a similar state of vigour, but still closely surrounded by pine branches, showed signs of considerable frosting. The first growth of the oak in dry, cool, early summer conditions is frequently short, and the wood is usually well ripened and hardy by the following winter, but warm moister conditions prevail in August resulting occasionally in prodigious lammas growths; in a mild autumn, nursed by enveloping pine-branches, this growth might remain soft and sappy until a sudden sharp frost dealt it a severe blow: whereas lammas growth in more open surroundings would tend to harden off earlier and thus be more resistant to autumn frosts.

At Rendlesham the plantations have now advanced one stage farther. The thicket is the only stage at which pine can be usefully slashed. Four years later the lowest branches are suppressed or dead, those which would form the lower crown have already been slashed, and the tree is only maintained by the upper crown which, now approaching 18 to 20 feet in height, is out of reach. The oak, still at 3,000 per acre, are more than sufficient to cover the ground and the pine must be removed, local conditions of exposure governing the rate at which they may be taken. Each pine is interfering with several oak and, whilst the growth is even, a rule-of-thumb method of selection cannot be improved upon, taking, say, alternate trees in every row in the first instance. Two further intervals of 2 or 3 years should see all the pine removed.

There are objections to the method evolved: in the first place constant attention is required to ensure that the various operations are performed at the right time, and secondly the first thinnings of Scots pine at an age of about 15 years will be carried out at a loss, whilst the remaining pine will only just pay for their removal in the two subsequent thinnings. Where climatic conditions are not so severe it might be advisable to have larger pure groups of oak with groups or strips of pure nurse trees; some at least of these latter would then be able to stand farther into the rotation and thus provide a useful intermediate yield. The method has proved, however, that even under adverse conditions a crop of oak can be raised which now gives every promise of yielding timber of good quality.

SUMMARY.

Breckland soil types in East Anglia are suitable, but not the best, for the raising of an oak crop. Climatic conditions are severe, frosts in June and September being regular features, whilst frosts in July and August are by no means unknown.

Rainfall is low, in the neighbourhood of 24 inches per annum, and droughts are of common occurrence.

In these conditions good crops of oak can be grown by close planting with an intimate mixture of Scots pine to act as a nurse. Considerable skill is required in the treatment and ultimate removal of these nurses, but the method will probably extend the area over which a valuable timber species may be grown.

CONVERSION OF BIRCH SCRUB AREAS TO CONIFEROUS WOODLAND IN THE NORTH OF SCOTLAND

By ANDREW WATT

(*Forestry Commission*)

TO apply the term 'scrub' to the extensive areas of natural birch wood in the northern Highlands is possibly open to criticism. Some Highland glens, for instance Glengarry and Glen Affric, still afford instances of well-grown birch, but in general the quality of growth, the thin stocking, and the resulting waste of the productive capacity of ground under the usual covering of birch dissuades the forester from attempting to establish pure birch crops on any scale. Further, the practical economic difficulties due to distance from markets, and the fact that even now the outlet for birch for bobbins, one of its main uses hitherto in the Highlands, is being further curtailed by imports of better quality material, emphasize the need for converting such areas to more productive species.

The value of birch in the silviculture of coniferous woods is appreciated more in the northern European countries than in Britain (4) and there are justifiable doubts on the wisdom of any method of conversion of birch scrub areas to conifers that fails to take full advantage of the assistance that the birch can give, not only in the early stages of establishing the new crop, but also in the more distant future.

From the forester's viewpoint birch areas are normally good subjects for the successful growth of selected conifers; a forest condition is there ready-made. The following notes describe some of the methods that have been or are being practised in State afforestation schemes in the north of Scotland.

EVEN THINNING METHOD.

Treatment of Scrub. Even thinning-out of the scrub, leaving enough cover to provide shelter to the new crop; special attention should be paid to ensure that only trees with high crowns are left so as to avoid having to carry out a second 'scrub-thinning' operation too soon after the planting of the new crop. The scrub is thinned out either by felling, followed by the burning of brush that would interfere with draining or planting, or by ringing. The latter operation is normally carried out in the spring and should be done far enough in advance of planting to ensure that sufficient light is available to the new crop.

Planting. The choice of species is fairly wide, and will be discussed later. The planting distance is the normal for the species chosen and notch planting is usually employed. In general, little heed is paid when planting to the remaining scrub trees and the new plants are put in without regard to these, as, in theory, subsequent treatment will remove the remaining scrub trees when they begin to interfere with the development of the conifer crop.

Subsequent Treatment. Ordinary operations, such as the clearing of weed-growth, may be needed almost from the start: coppice shoots, birch seedlings, &c.,

may develop strongly and require attention. The time for the removal of the remainder of the scrub crop depends on many factors, the chief one of which is the demand of the conifer crop for more light and growing-space. Economically it is best if the removal by ringing, which is the most practical way, is carried out in one operation.

GROUP METHOD.

Treatment of Scrub. The 'group' method was started seriously at Longart State Forest. The following description is taken from notes written by those most closely concerned in the operation (2, 3). Natural gaps in the birch scrub, where these gaps are on ground classed as plantable, are modified and enlarged where necessary by ringing or felling to give clear areas of varying size, usually about half an acre or so, each blank 'group' being surrounded by a fringe of scrub trees which are left standing. The brushwood accumulated from the clearing of groups is thrown into the fringe of scrub remaining. Uniformity of shape of the groups is not aimed at.

Planting. Planting is on normal lines and is started on the edge of the group, fairly close to the scrub fringe, and working inwards towards the middle. In the case of small groups the planting distance is reduced, but over all roughly the same number of plants per acre are put in as in straightforward planting (2).

Subsequent Treatment. Apart from ordinary weeding, it has been found necessary to ring the edge trees of the fringes to allow the full development of the conifers near the perimeters of the groups. This job could be limited by keeping the line of conifers next to the scrub fringe farther into the blank groups.

The stage where subsequent treatment of the scrub fringes, apart from that mentioned immediately above, must be worked out has not been reached, but it has been suggested that the regeneration of these fringes by young birch of good type may be the solution, particularly on sites where for general silvicultural reasons it is desirable to retain as far as possible the benefits of a mixed wood (3). The present writer believes that, in some cases at least, the conifer groups may eventually be joined up by the gradual extension of planting into the fringes, particularly where there is little chance of good-type birch coming in: but this extension would be desirable only where birch, even of poor quality, could not play an important part in preserving favourable soil factors, and thus prevent deterioration of the forest site.

ANDERSON GROUP METHOD.

Another group system has been tried out on lines suggested by Anderson in an article on a new system of planting (1). Anderson was concerned chiefly with a method of planting that would produce finer quality timber than is usually obtained by normal, evenly spaced planting. Anderson's idea originated from a study of Douglas fir growth, but he suggested its application to other species. Briefly the system consists of the formation of closely planted groups which are evenly spaced over the ground. Various spacings between the groups and within the groups themselves are suggested by Anderson and are fully described by him.

A site on Creagnaneum State Forest was chosen for a trial application of Anderson's system to a mixed and uneconomic hardwood scrub area. The site is a steep, sometimes precipitous, rocky slope, which carried a struggling crop of rough oak and other hardwoods. The choice of site was made for a number of reasons, the main ones of which were: firstly, the clearance or reduction of the scrub by normal methods (e.g. Even Thinning) would have been too costly; and, secondly, the danger of erosion resulting from widespread removal of scrub on the steep slopes. Groups were cleared by ringing and felling: approximately 130 groups per acre were aimed at; each group covered about 32 square feet of ground; the distance from centre to centre of each group was 18 feet. Plants were put in at 2 by 2 feet spacing in the groups, and the number of trees planted in each group was thirteen. Douglas fir was used for the bulk of the planting. So far the subsequent treatment has consisted of ringing some of the scrub trees on the edges of the groups to relieve the planted trees. As far as can be seen at present the trees on the edges of the groups are tending to dominate those in the middle of the groups, and this tendency may lead to irregular stocking in the later stages, and to the retention necessarily of a large proportion of the rougher outside trees as final crop stems; it is possible, however, that early thinning treatment in the groups may modify this tendency, but such treatment will probably be needed much earlier than a normal thinning operation if it is to succeed in its object.

STRIP METHOD.

Treatment of Scrub. The cutting out of scrub in strips and planting-up has been tried out. The cleared strips may vary in width, but do not usually exceed a chain, and the intervening scrub belts are left sufficiently narrow to allow the edge conifer trees in adjoining cleared strips to be close enough for the even spacing of final crop trees. The method of clearing the strips is similar to that employed in the Group Method.

Planting. Planting is on normal lines at the usual spacing for the species chosen.

Subsequent Treatment. On the assumption that weeding is carried out as usual, the earliest important operation is the elimination of the scrub belts when the edge conifers need more light and growing-space. This operation may be able to be carried out in one stage if the scrub belts are fairly narrow, but in practice at least two operations have been found necessary.

CLEAR FELLING METHOD.

Little description is needed as it is now generally accepted that this method is bad forestry. The unbalancing of the water relationship, the loss of shelter, and the danger of erosion are only three points against this method. A fourth point, amenity, is of importance in certain Highland localities.

CHOICE OF SPECIES.

In all but the Clear Felling Method the choice is limited to shade-tolerant species. Without going into details of site variations the following species are considered the most useful:

Norway Spruce (*Picea abies*). This tree is that most generally used on birch scrub sites. It is tolerant of a fair amount of shade, remains healthy even when left too heavily shaded for overlong, and quickly responds to an increase in light intensity.

Sitka Spruce (*Picea sitchensis*). This species is not ideal, but is useful where less favourable soil conditions make the choice of Norway spruce risky. It is not shade-tolerant to the same extent as the other species in this list, suffers considerably from aphis attacks if over-shaded too long, and is slow to recover if relieved at that stage.

Douglas Fir (*Pseudotsuga taxifolia*). Its usefulness is limited by its site requirements. On a moderately dry, stony, or rocky site this species grows well. It is tolerant of a fair amount of shade, and, indeed, grows more cleanly and evenly if shaded in the early years of growth than in full light.

Western Hemlock (*Tsuga heterophylla*). It is one of the most successful trees for planting scrub areas. It stands a great amount of shade and does not seem to suffer to the same extent as other species from rubbing and whipping by any scrub trees that may be interfering with it. It is, however, probable that heart-rot may be troublesome.

Western Red Cedar (*Thuja plicata*). Experience of this species is limited, as, where tried out on scrub areas, it has never succeeded in making a satisfactory crop owing to disease (*Keithia thujina*). There seems to be no particular reason why this species should not be useful, except that its silviculture is not at present sufficiently understood.

Other Species. The writer has no knowledge of the use of Silver fir species (*Abies* spp.) in scrub conditions in the north Scotland region. From their natural characteristics two species at least, *Abies nobilis* and *Abies grandis*, should be well suited to scrub conditions, and there is evidence that both these species grow well on comparable sites.

CONCLUSION.

No stress has been laid on the desirability of considering amenity in the tackling of scrub conversion, but there is no doubt that in certain glens in the north Highlands amenity can now no longer be disregarded. To the forester the appearance of a felled scrub area or of one with a young crop of conifers over-topped by gaunt and lifeless relics of the scrub crop is as much an eyesore as it is to the critical public. On this score alone the Clear Fell Method can be ruled out and the Even Thinning and Strip Methods are suspect. The Group Method and any modifications of that method along natural lines seems to provide the answer and at the same time to combine with the preservation of amenity those silvicultural and economic advantages which must be secured in any scheme of the kind. A criticism of the Anderson Group Method might be that the productive capacity of the ground is not as fully utilized as it should be.

In the execution of the conversion of scrub areas to conifers, past work has shown that the following point has not been fully appreciated in some cases. In any method involving the retention for a lesser or greater length of time of part

of the scrub crop it is essential that no tree should be planted in such a position that its development will be interfered with by the scrub crop before the need for general attention to the remaining scrub arises. This error may be avoided partly by ensuring that the scrub is adequately dealt with before planting and partly by anticipation on the part of the forester at the time of planting. It is uneconomic to cover the same ground for the same general purpose too frequently in the early stages of a plantation.

Much interesting work remains to be done on scrub areas. It is not possible to forecast with certainty the future trend of the silviculture of these areas, but the following are points which require further investigation. It should be possible to find an economic use for the better type of scrub trees that have to be removed, at least in those localities that are reasonably well served by roads. Perhaps some knowledge of the working of coppice areas in England would be useful to this end. Where the method adopted involves the retention permanently of a proportion of birch, there is no clear way at present of ensuring the satisfactory continuity of good type trees. Resort to artificial methods may be necessary. There is not enough information as yet on the future development of certain species of trees under scrub conditions: this applies mainly to newer species such as *Tsuga* and *Thuja*. The use of other species, not hitherto tried, could be extended experimentally.

SUMMARY.

A general note on birch scrub areas in the north Highlands is followed by a description of five methods employed in the conversion of birch-scrub areas to conifers. The methods are 'Even Thinning', 'Group', 'Anderson Group', 'Strip', and 'Clear Felling'. The treatment of the scrub crop in the use of each of these methods is described, and the system of planting and the subsequent treatment necessary are referred to. A list of the species used for planting is given together with notes on their individual suitability. The choice of method is discussed and the opinion expressed that Group Methods are on the whole the most desirable. In conclusion some errors to be avoided are pointed out and lines for further investigation suggested.

LITERATURE REFERENCES.

(1) Anderson, M. L.: *The Scottish Forestry Journal*, xliv, Part 2, pp. 78–89.
(2) Murray, R.: *Journal of the Forestry Commission*, No. 16, March 1937, pp. 142–3.
(3) Oliver, F. W. A.: ibid., pp. 123–5.
(4) Penistan, M. J.: *Quarterly Journal of Forestry*, xxxviii, No. 2, July 1944, p. 87.

THE LON MOR: TWENTY YEARS' RESEARCH INTO WASTELAND PEAT AFFORESTATION IN SCOTLAND

By J. ALAN B. MACDONALD

(*Forestry Commission*)

THERE is a special fascination in coaxing useful plantations to arise 'In the wide desert where no life is found'. What follows is the story of 20 years' work to that end by the Research Branch of the Forestry Commission on as derelict a stretch of Highland peat-bog as one could wish to see. Between these upper regions of hill-top and mountain, which by reason of sheer altitude must remain beyond the aspirations of the forester, and the eminently plantable lower reaches he may acquire or merely covet, there lies a derelict peat-clad land which in north and west Scotland alone runs into many thousands of square miles. Selective grazing by sheep or deer, and, in this region of high rainfall, the tragic practice of moor burning, have hastened the process of regression into utter wasteland.

Exactly 20 years ago a Research Officer of the Forestry Commission seeking a site for experimental plantings on such waste lands found what he wanted at Lon Mor. If anything the area was worse than typical—which was all to the good. In that year, 1925, a minimum of initial drainage was done, and the first experiments were laid down. Lon Mor is simply the Gaelic name for Big Waste. It lies on a wide, rather exposed shelf of acid moine schist 400–500 feet above sea-level and about a mile north-west of the Great Glen between Fort Augustus and Invergarry in central Inverness-shire. Besides a series of flats or basins, in the centre of which the peat may be as much as 12 feet deep, both peat-clad rock ridges and tough-peat-covered moraines are included. But it was mainly on account of the low-quality deep peat-bogs available that the Lon Mor was chosen. When selected, *Scirpus*, Cross-leaved Heath, and scanty sickly heather covered everything except a narrow margin where *Molinia* flourished by one of the sluggish natural drainage channels. Only here and there in the basins could Cotton grass or *Molinia* be found with any great frequency. There was much sphagnum and surface water at first. It is recorded that when the 'find' was reported to the District Forest Officer, that worthy, with a characteristic grimace, forthwith pledged himself to carry everything that could be grown at Lon Mor down to Fort Augustus on his back.

Following soon after investigations which had revealed the completely superficial nature of the root system adopted by spruces on wet types of peat[1], it was decided from the beginning that facilities for shallow rooting must be provided at Lon Mor. In consequence a new inverted thin, or shallow, turf was employed; through this turf the plant was notched and its roots spread on the surface of the

[1] H. M. Steven.

bog. The designer[1] was from the first convinced that turfs of like depth (about 5 inches) must eventually be produced by a plough of sorts, and it is well to remember that everything prepared by manual labour 20 years ago conformed in some degree to the plough work which would inevitably follow. As a matter of fact a very crude form of plough was designed and tried about 1926, but it was immediately obvious that further progress was at that time impossible for want of suitable tractor power.

It is interesting to find that even in 1925 the evidence against direct planting into the surface of the peat was so fully appreciated that no direct planting was done until 1927, when the need for a small demonstration plot of direct notching —as a sort of datum line—had become obvious. It is even more interesting to note that the originator of this system of shallow turf planting was so convinced of the need for facilitating immediate surface rooting that he did not employ the comparatively well-known high (or Belgian) turf system at all. Actually 3 years were to elapse before any proper Belgian turfing was introduced at Lon Mor, but for several years thereafter the tendency was to depart from the shallow turf in favour of the Belgian type. There were two reasons for the departure: peat is more easily cut below the tough rooty layer (i.e. at 10 inches than at 5 inches), and by 1928 the possibility of securing tackle to provide turfs mechanically was at best remote. Belgian turfs were in favour from 1928 until 1935, when they gave place to thin vertical slices of turf. There were several reasons for this. Firstly, a draining-and-turfing-in-advance experiment had shown that heavy Belgian turfs tended sooner or later to sink into the surface of the bog and become amalgamated with and sodden like it. Secondly, direct evidence was secured in other experiments to the effect that a group of shallow turfs—doubtless by providing an increased area of suitable rooting medium—gave better results than either a single shallow or a single Belgian turf; and thirdly, the new vertical slice turf left a deeper and therefore better drainage channel than the original, horizontal-shallow-turf system did. There was still no immediate hope of turning out the required turfs by mechanical means, but the new method was making the best use yet of manual labour and the ordinary draining tools. The point to observe is that we were back again to shallow turf within 10 years. More recent work (none of it at Lon Mor) has shown how markedly better is the start of tree plants where *complete* shallow turfing had been done, and last winter may with reason be remembered in the annals of moorland afforestation as the date of the first successful complete shallow ploughing of difficult peat land. The tools were a caterpillar tractor and a Massey-Harris Prairie Buster plough, the place Minard Forest in Argyll.

Having outlined the trend in the development of turf-planting it may be well to turn now to tree species as, with experience, they came into or fell from favour in the course of the 20 years. Only two species, Sitka spruce and Norway spruce, were planted as indicators in the earliest experiments. Even when dressed with phosphate, Norway spruce never made much growth and it was usually omitted in later trials. Sitka spruce with phosphate made a good start and despite

[1] M. L. Anderson.

the check which invariably follows exhaustion of the manure, its use as the main indicator species has been continued—latterly in mixture with pine, when the check is less marked. It should be made quite clear, however, that only on the best of the basin sites does Sitka spruce approach *Pinus contorta* in vigour.

White spruce has been a failure, but *Picea omorika* has done better than any other spruce and only the difficulty in securing that species in quantity has prevented its more general use.

Scots pine, although planted on spare turfs in 1925, did not get a fair trial because of dreadful damage by blackgame which persisted until about 1930; then the pests practically disappeared. This pine was not given the advantage of any initial applications of phosphate in the earliest years. It was, therefore, about 1928, by which time some pine had been top dressed and were looking well despite continual blackgame pruning, that the pine began to make a good impression. Naturally the blackgame damage prevented shoot measurements of pine showing up well in assessments, but their root development had been unchecked. *Pinus contorta*, first planted in 1926, was, despite the blackgame plague, quick in asserting its value as a pioneer species on almost shocking types of peat. While it has never developed any characteristics which render it less desirable—unless perhaps its susceptibility to roe-deer damage—Contorta pine is now much more closely challenged by Scots pine. It is obvious, however, that the American tree with its short branches is inherently better suited as a nurse for spruce than our own pine. There are undesirable types of *Pinus contorta*, but we had neither the clumsy, heavily branched coastal variety nor the thin, miserably branched interior one at Lon Mor. Mountain pine, also planted in 1926, with its painfully slow rate of establishment has only in the last few years made any real claim to usefulness, but it does eventually cover the ground better than the other two. One of the unexpected results at Lon Mor is the way in which Weymouth pine has continued to grow, if only in an unhealthy way, on wretched peat and in full exposure.

Four larches—Hybrid, Japanese, European, and Dahurica—have all been planted. The first of these is best, the last died out, and the European is most unhappy. Phosphate dressings are really essential if vigorous growth is to be established and maintained—perhaps more so than with any other species. The larches were first planted in 1927 and did so unexpectedly well that Japanese larch has generally been used as an indicator species along with Sitka spruce and *Pinus contorta* ever since. Two points about the Japanese and Hybrid larches call for remarks: they seem to require close spacing if they are to make steady growth and they may need a second dressing of phosphate. In the one (1926) experiment in which they have been given a fair trial, Douglas fir might be classed among the unexpected, if limited, successes and so might Nobilis and Balsam Silver firs. One is somehow less surprised to find Hemlock doing quite well or indeed to know that it and Omorika spruce are the two most successful species in the unslagged section on a very poor type of peat. Among conifers that failed were Thuya, Lawson's Cypress, and *Cryptomeria japonica*. Practically every common hardwood failed, including birch and rowan, but excluding Grey Alder—although

even it fell off quickly in growth after about 5 years. The experiments in which the majority of these species were compared are of a simple type which might well be employed in standard pilot plots for pre-testing new or unusual types of ground. There is little reason why the layout should not be standardized to contain a fixed number of lines each of a different species, and in all plots stocks of identical origin should appear. The results would not only provide data to show how the various species reacted to the sites, but would make it possible to assess the sites themselves with a valuable degree of precision. As distinct from comparative species trials, no race or provenance studies were established at Lon Mor except with Scots pine and to a much more limited extent with *Pinus contorta*. The subject is one which cannot be expected to provide much information for some years.

Having followed up the history of turfing and of choice of species as they were developed at Lon Mor, mention may be made now of some minor projects into which the 52 registered experiments and upwards of 30 preliminary trials carried out thereat can be classified. This leaves to the last the big field covered by manurial tests. The very first year saw an experiment laid down to investigate the effect of shelter and one or two designed to discover the best age of plant. Shelter was found to be of secondary importance to the presence of phosphate. A curious incident concerning the sheltered plants comes to mind: every alternate plant was in the lee of a small shelter of fresh pine boarding; but although the nearest pine wood was several miles away the sheltered plants were almost at once attacked by weevils although the unsheltered ones, not a couple of feet away, were scarcely touched. Two-year one-year spruce transplants had the lowest losses and made the best initial growth in the age and type trials. Somewhat allied to these age of plant tests are the direct sowings which have been singularly successful when carried out in the presence of phosphate; so much so that when ploughing becomes the standard practice on peat, sowings may yet displace planting. To avoid complicating the story when outlining the development of turf-planting, reference to the method of plant insertion was intentionally omitted. At first the inverted single shallow turfs were either holed by a circular spade (Belgian spade) which removed a plug more or less intact and reaching right through the turf, or were notched by an ordinary spade from outside to centre. By the former method the plant was set in the hole and the plug replaced tightly; in the latter the plant was slipped into the notch until it stood vertically at the centre of the turf with its roots spread below the turf and on top of the original ground surface. Because it was adequate, and cheaper, the so-called Side Notch method was continued at Lon Mor and indeed has been widely used elsewhere. The round plug method was dropped so far as shallow turfs were concerned, although it was still used in any standard Belgian turfing.

Spacing between plants has not been a specific study at Lon Mor. The earliest experiments were planted at unusually close spacings and were criticized later because these were so much removed from everyday practice; but they were essentially short-term tests concerned only with the comparative behaviour of the

plants in the first few years as a result of the differential treatments. The criticism has been repeated, for it is difficult to convince practical foresters that it is desirable sometimes to depart from the strictly normal in order to limit the area of an experiment and thus reduce inherent site variation which might otherwise outweigh the effect of any treatment under test. Bearing on plant spacing, Anderson's group system introduced in 1928 was something definitely original. It combined two ideas: (1) locally close planting with all its recognized advantages (with—on such poor ground—the possibility of adding a greater concentration of phosphate to the square yard); (2) no increase in the number of plants required per acre. The groups contained 13 trees each; only one or two in the centre—and these were usually Sitka spruce—were intended as timber producers, the rest were there simply to assist the one or two final crop trees to that end. The essential fact about the group system is that it was designed when thinnings in north Scotland were unsaleable and likely to remain so. It was primarily an attempt to employ, to the maximum silvicultural advantage, the mass of second-rate stems.

From the beginning Lon Mor has played a very prominent part in the researches into the effects of manurial dressings upon conifers on poor quality sites. Indeed of the 80 and more trials there laid down, nearly 50 have had some connexion with this subject. Basic slag or phosphate in some other form has entered into most of these experiments, for, as early as 1928, the futility of attempting to grow trees on such conditions without phosphate had been amply demonstrated. A 1928 experiment introduced two new forms, both proprietary —*Semsol*, later believed to be half superphosphates and half ground mineral phosphate, and *Ephos*, simply an Egyptian mineral phosphate. Experiments continued to be laid down to find how plants reacted to phosphates of all sorts, in all sorts of doses and combinations thereof right up to the war. A very recent assessment of many preliminary trials points to ground mineral being the best of these phosphates, and of it 1½ ounces per plant seems to be sufficient as an initial dressing.

In addition to a phosphate (Basic slag), both a magnesium salt (Epsom salts) and a potassic manure (Kainit) were tested in the first year's experiment and others have since been tried. Magnesium sulphate did produce a slightly beneficial effect, but no other source of magnesium did so. Potash (sulphate) also showed positive reactions, but nothing comparable with those obtained with phosphate. The effects of magnesium and more so of potash were much enhanced when these were applied to trees which had also received phosphate. This fact led to quite a series of experiments being put down with a view to arriving at a really suitable complete manure. Dr. A. B. Stewart of the Macaulay Institute co-operated in this work. It will be some time before the results of these complete fertilizers can be assessed, but the signs are that complete manures will not be so much better than phosphate alone as to be worth while. As a nitrogenous fertilizer sulphate of ammonia proved fatal in most cases at Lon Mor. In the latest complete manures Dr. Stewart introduced, as the source of nitrogen, a hoof and horn manure as it was much slower acting: to supply slow-acting potash both

granite dust and basalt dust have been used in the mixtures. No tests of compost have been carried out at Lon Mor, although active peat, from stands where the tree species concerned was growing vigorously, was tried about 15 years ago, with no apparent result. Some trials of Dr. Rayner's composts have been laid down in an adjoining area, P. 22 Inchnacardoch, which is really an extension to Lon Mor.

About 1930, when news of the stimulating effect which basic slag was exhibiting at Lon Mor and elsewhere had reached the forests, orders for tons of the stuff were placed. In the interest of caution headquarters issued the dictum: 'An ounce of patience is worth a ton of slag.' On the face of it this was justified then, but now the ratios rather call for inversion. Naturally quite a number of the early experiments were rendered obsolete by the results supplied by later ones. For instance, it was soon obvious that phosphate was essential to conifer growth on the poor peat types, so that tests on various subjects laid down before the days of phosphate have had to be repeated with it. Many of the early results of Lon Mor experiments are taken for granted now—indeed some were accepted even before they had been subjected to proper test. Naturally enough, in forestry as elsewhere, the research side came in for much criticism and banter from the start. H.1.d.—the research standard head of accounts—was considered fair game. 'Hid' the foresters called it. In the north-west the branch has been given some other and more picturesque titles in what might be termed bastard-Gaelic, that tongue having to be bolstered up to render it fully effective.

Further symptoms of the interest which Lon Mor and other experimental reserves were arousing among the practical men came in a mild rash of divisional experiments in forests up and down the country. These, from being very simple in the early years, became more and more involved as time went on—what with controls and replications—until foresters and officers realized that it was one thing to plan an experiment, but quite another to keep track of what had been done. Indeed it is doubtful if what was done is ever as important as *knowing exactly* what was done. For years it has been the practice to ask visitors for suggestions as to new trials which might be laid down, and it has been quite remarkable how often it has been possible to say that their suggestions had already been tried. Instead of a miasma or the 'putrid vapours' which the old writers on peat-mosses so freely mention, enthusiasm seems all along to have arisen from the boggy surface of Lon Mor and to have stimulated all who were connected therewith. The thrill experienced when, about 1927, the then Technical Commissioner made his first visit, must have touched visited and visitor alike, judging by the expansion of the work on the poorest peat types which followed, both within Lon Mor and beyond.

In all fields of research it would be depressing to find pet hypotheses disproved, as they repeatedly are, but for the fact that there are always new ones to try, and because knowledge increases and progress arises as much from negative as from positive results. It has been thrilling to realize how much less impossible it was becoming each year to afforest difficult types of moorland. It is heartening to note that the long-threatened bogy—sudden termination of growth—has not yet

Fig. 1. The Lon Mor in 1926. An area turfed

Fig. 2. The Lon Mor, October 1945. Sitka spruce planted in 1928 on shallow group turfs behind figure, and on Belgian turfs in foreground

PLATE III

Fig. 1. The first attempt at ploughing. The Lon Mor, 1927

Fig. 2. The Lon Mor, October 1945. Pine species planted in 1926 as a shelter belt on an exposed peaty ridge, with (right) and without (left) basic slag

PLATE IV

appeared. And so at Lon Mor and in its extension areas we go forward with enthusiasm undiminished; with hope and confidence increased. We are on the eve of tackling the worst the Lon Mor can provide in the way of peat (and that is saying a good deal) by tractor and plough,[1] and considerable success is assured. There will be many old tests to repeat under these new conditions. We have passed through a period when there seemed little hope of securing the necessary mechanical equipment to deal with basin peats, and that led to a partial emigration from Lon Mor and to working more upon the thinner slope-peats on which ploughing might be more feasible; but now wide-track caterpillars and better ploughs have made possible the mechanization envisaged when Lon Mor was first selected. Still tougher peat knolls and ever more intractible bogs will therefore come within the forester's power. On then, 'to-morrow to fresh woods—the wilderness and the solitary place shall be glad for them'.

This account is published by kind permission of H.M. Forestry Commissioners.

[1] The area has, since the above was written, been successfully ploughed.

CULTIVATION OF CHESTNUT COPPICE AND ITS UTILIZATION IN WAR AND PEACE

By W. ANGUS MUIR, M.C.

(*Forestry Commission and Ministry of Supply*)

INTRODUCTION.

SINCE the autumn of 1939 those woodlands of south-east England which are managed under systems of Simple Coppice and Coppice-with-Standards have played a very important part in providing an extremely wide range of commodities which were essential towards meeting war-time requirements of agriculture and commerce and the pressing demands of the Fighting Services. These coppice areas have, moreover, made a most valuable contribution towards the general economy of British forestry, because had it not been for the output of many million cubic feet from coppice during the war, thousands of additional acres of young high forest plantations would have had to be sacrificed to obtain an equal production of pitprops and defence materials. This contribution has been made by crops which reproduce themselves and whose cutting has, therefore, in no way added to the great problems of post-war reafforestation.

CULTIVATION.

This article deals primarily with Spanish chestnut (*Castanea sativa* Mill.) which is now, and is likely to remain, the most important species under coppice cultivation. War conditions have, however, made possible a temporarily increased exploitation of other associated coppicing species such as ash, oak, hornbeam, alder, birch, and hazel, to which some references will be made.

The figures for acreage of Coppice and Coppice-with-Standards as given in the 1924 Census (2), totalling for the United Kingdom some 530,000 acres or nearly 18 per cent. of the then recorded woodlands, is interesting mainly as being indicative of long past conditions, but the figure for the area under review (Kent, Surrey, Sussex, and Hampshire) at about 240,000 acres or 58 per cent. of the woodlands represents much more closely actual cultural systems which growers have attempted to maintain on a more or less regular rotation to a much greater extent than in any other part of the kingdom. There are no complete figures to show how much of the 240,000 acres can be correctly classified as chestnut, but on a conservative estimate there must have been at least 100,000 acres of which unfortunately a large proportion was very poorly stocked.

Writing in 1928 Taylor (6) expressed a fear that there was danger that supplies of home-grown chestnut might become unduly restricted to the detriment of the cleft chestnut fencing industry, and said: 'The whole question merits a place in forest policy, at least equal to the dimensions the industry has attained and its potentialities for adding permanently to the over-thin ranks of rural workers.'

On the evidence now available, it appears that all normal demands could have been met by prompt and proper care and renovation of suitable existing areas of chestnut without recourse to new planting generally. Most unfortunately, the subject does not appear to have received the well-merited attention referred to above.

It is convenient at this point to examine in some detail the chief defects of cultivation and management, many of which, had they been tackled seriously even as recently as attention was called to the subject by Taylor in 1928, could have been practically eliminated by now owing to the short rotation of the chestnut crop. At the same time suggestions will be made of the principal improvements which should and can be effected.

1. *Difficult Extraction.* A 'cant' (unit of area sold as a separate lot varying usually from ½ to 3 acres) which adjoins a hard road will usually fetch at auction nearly double the price realized for a similarly stocked cant lying possibly within a few hundred yards, but not directly approachable by lorry. The reason is that to extract coppice produce, which is all prepared in the wood, is not just a question of direct loading on road vehicles of a few score of large trees or even a few hundred thinnings per acre, but one of moving literally thousands of small pieces. Where a lorry cannot get to the cant boundary the amount and nature of the double handling enormously increases the costs of operation. Assuming suitability of soil, a first principle should be, therefore, to raise to the maximum the stocking of all areas with good 'clearance'. Were this to be done the output from the selected areas would be so increased as to make possible the release of considerable hinterland areas for more valuable high forest. This fortunately fits in well with another aspect of forest management, namely fire protection. A layout with a belt of anything from 3 to 5 chains deep of chestnut parallel to and adjacent to a public road or made-up track would provide ideal clearance for the coppice and at the same time very efficient fire protection provided the chestnut is kept as a pure crop and fully stocked.

During the war the presence of very large areas of 'overgrown' coppice (that is of larger size than the optimum for general trade requirements) has made possible the meeting of very heavy special war-time needs. At first sight it would appear that this must be contradictory to the previous statement that there was a good peace-time demand for chestnut, but it is not so. In practically every case the overgrown crops are those which were not sold at the proper time, either because extraction was too difficult for economic working even at the lowest prices which owners were willing to accept, or because the chestnut yield per acre was too low owing to the admixture of other species.

2. *Presence of Standards.* It is now abundantly clear that to get the best results chestnut must be grown as a pure coppice without standards, and this has proved equally true in the emergency conditions of the past 6 years and for normal peace-time working.

First-class mature standards have often been sterilized during the war period because they were growing over semi-mature chestnut which was still of sufficiently good quality to warrant its preservation to maturity. Where it has been

necessary to fell standards in growing coppice the difficulties of felling, clearing up, and extraction have been greatly increased at a time when labour was so short. The main objection, however, to the attempt to grow two crops on the same land at the same time is cultural. In the few cases where any real attempt has been made to maintain a proper graduation of age classes in the overwood, the original underwood has now been debased to a weak valueless scrub. In the vast majority of cases one actually finds a more or less even-aged overwood with the underwood doing fairly well in inverse ratio to the number of standards per acre, but never reaching optimum growth.

The extent and nature of damage to chestnut underwood by standards has been described and illustrated by le Sueur (4), who instances 56 blanks and useless stools as a result of overshadowing by a single normally crowned oak. The original spacing of the stools was 5 by 5 feet. Old beech standards are even more devastating than oak, but fortunately they are not prevalent except in some of the North Downs areas. Le Sueur also mentions the interesting attempt in a few estates to combine a thinly stocked high forest of larch with chestnut underwood. In actual practice this system is very difficult to control and does not appear to have produced results which could not have been greatly improved on by completely separating the two crops, and obtaining the same output from a smaller total area.

3. *Inadequate Stocking.* This fault, while often due to the presence of standards, is also found in simple coppice, where it is due to failure to maintain the growing stock of stools. Many growers, thinking only of the usefulness to them of the reproductive powers of chestnut, have quite failed to notice the progressive depletion due to complete stools dying out from one cause or another. Improvement of stocking can best be done in the case of small blanks by layering from adjoining stools, but larger gaps, say more than 20 feet across, caused usually by standards, can only be made good after the removal of the standards by a combination of layering and beating up. It must be stressed that planting up of individual gaps is a complete waste of time, as the introduced plants have practically no hope of survival and the only method is to layer.

Buyers, when deciding on the value of a cant, estimate the total number of poles of usable size and quality in several diameter categories according to the products they intend to manufacture. A good stocking, therefore, directly increases value, while a poor stocking debases it not only in terms of total stock, but by the much higher proportion of twisted stems of low commercial value.

4. *Coppice of Mixed Species.* During war-time the importance of growing chestnut pure has been rather concealed because it has been possible to market practically every species at reasonable prices. But in peace conditions those who wish to buy chestnut are not usually interested in other species and look on them as a liability, because the sale agreements always specify that all species must be cut and cleared. It is not so much a case of placing a low value on the other species, as making an actual reduction in the price offer for dealing with them. At auctions, it is interesting to watch the change in bidders as well as bids whenever a mixed cant is offered. The fencing companies' agents and hop-pole buyers cease to take

any interest, and the opening bids are likely to be only as many shillings per acre as pounds for a chestnut cant.

It must not be imagined, however, that there is no demand in south-east England for species other than chestnut, but the demands are definitely restricted and localized. The available growing stock is greatly in excess of requirements and is likely to remain so. This applies especially to hornbeam, which passed its zenith when the requirements for charcoal for the local iron-smelting industry declined and more recently has had a further blow in the use of coke and electricity instead of charcoal for the drying of hops in the oast houses. Hazel coppice also covers a very much greater area than is now required, owing to changes in agricultural practice. The fact that large quantites of Hazel have been marketed during the war to provide rods to make fenders for Admiralty craft of all shapes and sizes must be looked on as a non-recurring utilization. Economic land planning certainly points to a heavy reduction in the mixed coppice acreage, and its transfer to high forest as soon as practicable.

5. *Effect of Poor Workmanship.* With age and the frequency of cutting, the size and height of chestnut stools is bound to increase, but they should be kept to the minimum by really low cutting. This is especially important with the perimeter shoots, as their butts tend in any case to sweep out, and if they are not cut tight the ensuing shoots tend to sweep still farther out. There can be no other forestry operation in which the usual contract clause about performing the work 'in a proper and workmanlike manner' has deeper significance. A bad workman sometimes attempts to get slightly shorter but straight poles by cutting above the sweep, but if he is allowed to do this the next crop will be a sorry sight. It has been quite a common occurrence during the war to have to cut off as much as 2 feet from the butt of a properly felled chestnut pole to get a straight enough section for a pitprop, and the wastage in cleaving similar material is even greater. Close stocking partly minimizes but does not cure an initial curve, and if the 'springs' (first-year shoots) sweep outwards the resulting crop is bound to be depreciated.

6. *Lack of Drainage.* At one time it was a normal practice in well-managed coppice areas that after cutting and clearing up of waste was completed, the estate staff cleaned out to original depth all subsidiary drains in the cut area, and of course the main outfalls were kept open or cleaned as often as might be necessary. It is safe to say that by the beginning of this century this practice had been abandoned in many areas and by 1939 was only carried out spasmodically even in the best managed properties. Much of the good chestnut coppice is to be found on soils which if not really heavy are at least strongly retentive of moisture. Lack of proper drainage in such circumstances has at least two specific ill effects on chestnut coppice. First, a general departure from optimum conditions resulting in a slower growth per annum. This at once lowers value as well as increasing the rotation necessary to produce a given average diameter. The decrease in value occurs because of shorter dead straight sections of annual height growth, which reduces the proportion of long cleaving lengths which are the most valuable. Second, soil conditions are provided which are suitable for the

development of species of *Phytopthora* causing root rot. The symptoms are the dying of groups of stools rather than separate scattered stools. Recorded loss in the producing districts from this cause is so far nowhere widespread, but in the aggregate represents a serious loss which may well increase considerably in incidence unless proper and regular drainage is introduced (reintroduced will be sufficient in most places). This subject has been investigated by Day (1), who stresses that where drainage is necessary at all it must be thorough and should be of sufficient depth to improve soil conditions in at least the top 2 feet. Day also emphasizes the advisability of confining chestnut to fertile and, if possible at the same time, to naturally loose well-drained soils.

8. *Damage by Frost.* Chestnut is liable to damage by spring and occasionally by autumn frosts. The fact that spring frost rarely cuts back the shoots by more than an inch or two, that fresh leaf flush and shoot-making come very quickly after the frost, and that height growth may not suffer much on the average, may tend to mislead one as to the real extent of the damage from the point of view of the requirements of the purchaser at the end of the rotation and consequent loss to the grower. Every time a leading shoot is cut back by ever so little the fresh shoot comes out at an angle, and the lengths of straight material for cleaving and pitprops is reduced. The rotation is so short, sometimes only 9 years, that the poles have not time to obliterate the outward traces of temporary setbacks as is so often done with mature timber, including chestnut. While it is impossible to select only areas which are normally completely free from frost, it is obvious that for good financial results one should not attempt to maintain chestnut coppice in known frost holes.

9. *Cutting out of Season.* The normal cutting-period prescribed in agreements is from mid-October to the end of March, and this is usually strictly enforced. Under war conditions it has not been possible to adhere to these dates in every case, and a lot of cutting has gone on continuously throughout the year. The ill effects have not been so great as many people feared. Many growers considered that the vitality of the stools would be permanently affected, but the past 5 years have produced no evidence to confirm this. There is, however, bound to be some loss, because cutting after the end of April reduces the average length of the first-year shoots, and so will probably necessitate an increase of one year in the current rotation. The greatest possibility of loss from summer cutting is the danger of both spring and autumn frost. If shoots which are shorter than normal in any case are cut by frost, the result at the next cutting of the crop will be that the butt length instead of being 4 to 7 feet and the most valuable, may only be 1 to 3 feet and too short for economic cleaving. Such additional dangers, for which the grower is not compensated, could only be taken under exceptional circumstances of national emergency. It appears clear, however, that the cutting-season could be lengthened by about a month at each end without the least risk of adverse results.

CONVERSION OF COPPICE CROPS.

Having considered the dangers to avoid and the methods most likely to give success in the growing of chestnut coppice, it is opportune to consider briefly

what can be done with areas which should not be retained as coppice, whether on grounds of unsuitable soil, difficulty of extraction, being in excess of requirements, or any other grounds which show that high forest would give better results. This question is one of considerable magnitude in south-east England, which has the highest proportion of woodlands to total land area, and where such a high proportion of these woodlands is classifiable as Coppice and Coppice-with-Standards. On its proper solution may well depend whether forestry is going to make its full contribution to economic land planning, not only for the national good, but as helping to maintain maximum rural employment. The decision to be taken may not always be on pure forestry lines, as there will require to be very close consultation on local agricultural requirements and also on the requirements of the widespread cleft chestnut fencing industry.

The change cannot be made quickly now, because, owing to the legacy of the war, there will be a vast amount of work to regenerate those woodland areas where timber has been cut during the war and which will revert to scrub if not rapidly attended to, and such work must obviously take priority. By force of circumstances, therefore, conversion of coppice will be gradual, and the angle of approach will need to be not so much which areas can be converted first, but under what circumstances can conversion be delayed without undue loss and without creating further problems for the future.

In dealing with the problem of converting oak coppice, Ryle (3) considers that where the coppice is in thicket and is healthy, there is 'A strong argument in favour of retaining the present crop to develop up to pitwood size before the conversion to a heavier yielding species is undertaken.' He is dealing with a crop on a longer normal rotation than chestnut, but this makes no real difference except that any delay in converting chestnut would be less serious than with oak. Where, therefore, there is a relatively good and even stocking of chestnut, either pure or with an admixture of other species, which is more than 4 years old it should be left to the end of its normal rotation or whatever age will at the time give the best financial return, and the owner will then have at least a few pounds per acre to offset the cost of planting and establishing another species. In cases of really dense stocking, irrespective of species, it would be possible to postpone conversion still further by allowing the existing crop to go still longer. By continued retention of canopy, chestnut coppice will reduce itself to only one or two dominant poles per stool and will suppress to the extent of killing out most of the other species. By this latter method, the cost of establishing the newly planted crop can be enormously reduced. The revenue as a final coppice crop will have been lost, but many of the chestnut poles will be large enough to yield small saw timber from the butts, plus heavy hop poles and pitprops from the tops. It is interesting to note that out of a wide range of fellings in chestnut coppice which had been left to grow to quite large timber, no cases have been recorded of 'shake', which has frequently been found in planted trees of equal diameter.

Whether conversion can be carried out soon or late will be largely a question of labour and finance, but what is vital is that there must be no delay in making working schemes for the coppice areas, showing what should be aimed at, so that

all the operations necessary are carried out as part of a well considered plan, and not in a haphazard and hit or miss manner.

UTILIZATION.

There are few crops in which the utilization is so complete as chestnut coppice. The owner when selling stipulates that the whole of the area sold must be cut over completely and all the produce must be removed and the waste burned. Provided the crop is a good one very little burning should be necessary, because practically everything larger than twigs can be disposed of profitably by any operator who takes the trouble to make use of the many different demands which exist. A description will now be given of these demands, and as far as possible a comparison will be made between present and pre-war prices. During the war chestnut was required in certain specifications which occur in peace-time, and these are described from the point of view of interest, and as showing the great contribution which chestnut has made to the war effort and as emphasizing its adaptability, but prices will not be given in these cases as they were fixed under the stress of necessity and might therefore be misleading in assessing probable future financial yields.

Hop Poles. Practically all the poles used in the main hop-producing areas of south-east England are chestnut. (In part of Hampshire there is a small demand for large larch poles sawn quartered.) The demand for poles for this purpose is fortunately now fairly stable, as the total area under cultivation is fixed by the Hop Marketing Board, and sudden increases or decreases in demand which used to follow good or bad seasons, and which used to upset pole prices and rotations, are largely absent. Changes in the method of training the hop vines have, however, had a marked effect on the marketing of chestnut and consequently on rotations. The original method was to erect thin poles 13 to 14 feet long with a 1¼ inch tip diameter at the rate of from 1,750 to 2,900 per acre and the vines were trained up the individual poles. In about 1900 a system, now always referred to as 'Wireworks', was introduced in a hop garden in east Sussex and this method is now normal in all the large gardens and in the majority of the smaller. For this system 150 to 200 poles are used per acre, 16 feet long and 2½ inches minimum top diameter. A network of stout wire is stretched over the poles, and the vines are trained up cords, four to each plant. Round the perimeter of each garden there are still stouter poles ('outside wireworks') 18 feet long and from 4 to 6 inches top diameter, from which the wires are anchored to the ground. It is obvious that this method requires fewer but considerably longer poles than the former method, and may represent an average increase of the growing rotation by about 5 or 6 years.

The manufacture of all sizes of hop poles consists in cutting to specification and peeling (the further process of cold tank creosoting 3 feet of the butt is done by the purchaser). Average prices per 100 poles stacked at roadside:

	1939	*1945*
13 feet × 1¼ inches	15*s.*	60*s.*
16 feet × 2½ inches	65*s.*	240*s.*

Cleft Products. Chestnut is very suitable for cleaving, but it must be straight grown if a good yield is to be obtained. Quite small poles can be used, but the best output is obtained from pieces with top diameters from 2 to 6 inches. Larger sizes can be cleft, but the work is heavy and slow and the wastage is high. Some of the work is done by direct employees of the fencing companies, but much is undertaken by men who work up cants which they have bought, and market their produce to the companies and to neighbouring farmers. Even before the war the average age of cleavers was high, and the industry will probably have to make considerable increases in day and piece rates if it is to attract young men to what is really an expert trade. The principal cleft products are:

(*a*) *'Pales' for Fencing.* These vary from 3 to 6 feet in length with a girth of from 4 to 4¾ inches. They must not be more than their own thickness out of straight. They have to be peeled, blunt pointed at one end, and bundled tightly with wire. The reason for the pointing is to facilitate slipping between the wires in the fencing machines. Prices per 1,000 pales in bundles at roadside are:

	1939	*1945*
3 feet	30*s.*	50*s.*
3½ „	37*s.* 6*d.*	62*s.*
6 „	85*s.*	120*s.*

(*b*) *'Spiles.'* These are mainly used for farm fencing and hedge repairs. As, unlike pales, they have to be driven in the ground, they must be sharp pointed as well as peeled. The usual length is 5 feet (occasionally 6 feet), and the prices heaped loose at roadside are—per 100—1939, 17*s.* 6*d.* and 1945, 40*s.*

(*c*) *Cleft Rails.* Many cants yield none of these, because nothing is used which will not cleave four rails per length and this requires at least a 10-inch diameter. Lengths are 9 and 10 feet and prices in 1939 were 2*s.* and 2*s.* 3*d.* each at roadside. At present production is low but is expected to increase.

(*d*) *Manufactured Fencing.* This is made up in a very large number of styles and strengths. A good average chestnut fence 5 feet high suitable to stand up against cattle with three lines of wire and pales 2 inches apart could in 1939 be bought at 2*s.* 4½*d.* per yard delivered, plus 10 per cent. if creosote coated. Straining posts and struts, both square sawn, and intermediate posts half round for erection every 6 to 9 feet were charged separately. Supplying firms would erect the above type of fence at about 5*d.* per yard. All these prices should be advanced by about 75 per cent. for 1945.

'W.D. Trackway.' This commodity was a manufactured article similar to cleft fencing but stronger. It was used for many purposes including (*a*) laying of roadways over landing-beaches and adjoining sand-dunes for the passage of all types of vehicles from the landing-craft; (*b*) temporary repairs to roads and tracks churned up by heavy traffic in wet weather; (*c*) making up into large fascines which were carried on tanks for release into anti-tank ditches. These fascines were used specially by the Armoured Fighting Vehicles, Royal Engineers, which with their heavy mortars and demolition charges, were in no small measure responsible for the speed of the advance of our armies after the break out from the Normandy bridgehead.

Contracts for this trackway were placed by the Ministry of Supply Contracts Branch with twenty-eight fencing companies, who to meet the demand had to abandon practically all their civilian contracts. Even so the Home Timber Production Department had to assist in preparation of the pales and for this purpose alone bought and operated over 700 acres of chestnut coppice and in 12 months handed over to the manufacturers 8½ million pales. The total quantity of prepared trackway delivered to the Army was about 1,700 miles, of which chestnut must have provided about 95 per cent.

The specification for this vital commodity was: (*a*) lengths of pales, 3 feet and 4 feet 6 inches in equal proportions; (*b*) cleft pales (chestnut and ash), girth 4½ inches, minimum cross section 1 inch; (*c*) round pales (chestnut, ash, willow, hazel, birch, oak), diameter not less than 1¼ inches and not more than 2¼ inches; (*d*) ends sawn square. No peeling or pointing asked for.

The manufacturers had to make up these pales with three lines of wires, in sections of 10 yards for 3 feet pales and 5 yards for 4 feet 6 inches pales. In all cases the clear space between pales when wired up must not exceed 1½ inches.

Pitprops. In spite of the heavy demands on chestnut coppice for specific purposes for which other species were unsuitable, millions of cubic feet of props have been produced from it. Until shortage of labour made it necessary to supply unpeeled props chestnut was peeled with other species. With a view to the continued use of chestnut for round props when conditions return to normal it should be noted that when cut to short lengths and peeled it tends to split quickly and deeply in hot weather. One cannot eliminate small surface splits and in any case they do not affect strength, but deep splitting can be largely overcome by stacking in shade where possible and also by throwing the long shreds of bark over the stacks of props.

The chestnut areas of the Weald and east Kent are well situated for meeting the requirements of the small Kent coalfield, running as it does from east of Canterbury to north of Dover, but during the war much had to be sent away to meet the greater demands of south Wales and the midlands. No complaints were made against chestnut as such for pitprops, but complaint was made from time to time about twisted props. This, combined with the fact that much material had to be rejected in the woods owing to twist, strongly emphasizes the need to improve the general standard of cultivation.

Props supplied in chestnut varied from 2 feet 6 inches with 2½ inches top to 9 feet with 6–9 inches tops and prices from 7*s.* 6*d.* to 53*s.* per 100 lineal feet delivered plus a rail subsidy in certain circumstances. There was always ample raw material for the smaller props of 3 feet and under, but great difficulty was experienced in keeping up the supply of intermediate sizes, particularly the 4 feet × 4 inches and 4½ feet × 4½ inches for the Kent Coalfield and the 4 feet 6 inches × 3½ inches to 5 inches for South Wales which come within the range of sizes most suitable for cleaving. Pitprop production from chestnut yielded a considerably lower profit than any other form of its utilization during the war, and manufactured articles such as hop poles, stakes, and cleft pales were not controlled as to selling price.

Charcoal. All charcoal burning was at a low ebb before the war, and practically no chestnut was being used, as there were plenty of non-chestnut cants on offer at much lower prices. Even with the considerably increased war-time prices for charcoal, no one could afford to buy chestnut cants with the primary object of producing charcoal. On the other hand, it has been possible during the war to produce large quantities of charcoal from the waste after pitprop production, and many areas which owing to twisted growth could not have been worked economically for props, poles, or cleaving have been worked advantageously for national requirements by the addition of charcoal burning.

The characteristics of charcoal produced from chestnut were found to be such that it could be included with beech, hornbeam, birch, and alder (but not oak) in a special grade required in large quantities by the Department of Chemical Warfare for the preparation among other things of smoke screens which were so invaluable at sea, at landings, and for the crossing of the Rhine. It is of particular interest to note that there has been so far no reduction in the demand for this grade of charcoal as it is being used in the manufacture of penicillin.

It is of great importance that charcoal markets should be retained, because burning to produce a saleable commodity is a very different matter from cutting and burning waste material. In this way the net cost of converting unwanted coppice areas to high forest could be partly offset.

War-time improvements in the design of metal furnaces and their accessories can considerably reduce the capital outlay incidental to furnace burning both by giving improved output and by prolonging the life of the equipment.

The average price per ton delivered for charcoal (any species) in 1939–40 was £10. 10*s*. In 1945 prices ranged as under: restricted Species, £16; unrestricted Species, £15; graded oak, £16; screenings, smalls and dust, £6. 10*s*. to £7.

Home Defence. With the fall of France in the early summer of 1940, danger of invasion became serious, and in no part of the country more so than in south-east England. Immediate steps were taken to strengthen existing defences and to erect complete new systems in depth from the coast to London. Engineer Officers would spend the day siting trenches, strong points, emplacements, &c., work out the quantities and sizes required and ring up at night asking for delivery within 24 hours, presupposing that the Ministry of Supply, timber merchants, and coppice dealers held large ready-made stocks of a wide range of specifications which as a matter of fact they never had produced at all. Everything possible was done to bridge the gap while contracts were arranged and supply and delivery organized, and while there were inevitably temporary shortages in certain sizes and at certain places, it is gratifying that the defence lines were in fact prepared within the times laid down by the higher command. A very high proportion of these demands were met from chestnut.

For revetment purposes alone, the Ministry of Supply Contracts Branch arranged for and got delivery from the fencing companies of over 3 million square yards of cleft chestnut fencing in heights varying from 3 to 6 feet. The number of round pieces used as pickets, props, and poles will probably never be known but must have run into many millions. For such purposes as (*a*) obstruction poles

to upset airborne landings, (*b*) poles for aerodrome approach lighting systems to reduce the heavy casualties suffered by returning bombers, and (*c*) light Army Telegraph poles for maintaining the rapid communications on which a modern army is so dependent, for these and other purposes chestnut was largely used along with a considerable range of other species.

It is impossible to give anything like a complete range of specifications, but some of the principal were:

	Length (feet)		*Top diameter (inches)*
Defence pickets and poles	3, 3½, 4	×	2 to 3
	6, 8	×	3 to 5
	10, 12, 20	×	5 to 6
Aerodrome poles	26 to 40	×	4 to 6
Light telegraph	16 to 18	×	2 to 2½ (with 4 to 4½ butt)

Stakes. The consumption of stakes for fruit and vegetables is high in south-east England and chestnut is normally used. During the war, the demand for tomato stakes has increased considerably. An increased demand not due to war conditions appears to arise from the fact that some of the most popular heavy cropping desert apples are not so wind firm as the older varieties.

(*a*) Bean Rods: 8 feet long by 1½ inches tip in bundles of 25 have risen from 9*d.* to 2*s.* per bundle.

(*b*) Tomato Stakes: 4 feet long by 1 inch tip similarly bundled have shown the same increase.

(*c*) Fruit Stakes: 7 feet long by 1½ inches tip have risen from 4*d.* to 10*d.* each. All these prices are at roadside.

Fuel. While there is a general preference for oak there is a ready demand in many areas for chestnut logs, large and small, made from the waste pieces arising from other production, and at the present time demand so exceeds supply with available transport that high prices are asked and given. The preparation of chestnut faggots in the hop-growing districts accounts for practically every stick that is left when the other commodities so far mentioned have been prepared. These faggots are provided in large numbers by farmers for the hop pickers for fuel in their bothies.

Faggots are usually bound up with a 10-inch diameter and now fetch about 25*s.* per hundred lying in the wood against 8*s.* 6*d.* in 1939.

Labour Costs. It is rather difficult to arrive at average labour costs owing to the immense variety (in respect of age, stocking, &c.) of the coppice crops which are cut. Taylor (6) in 1928 refers to a figure of £40 per acre for cutting and working up a cant suitable for fencing. This would appear to refer to well-stocked cants with consequently a lot of material to be handled, and as such is a sound figure to start from when considering the labour force which should be employable when the general standard of growth has been improved. Taking the run of cants operated in 1938–9 including coppice-with-standards, labour costs appear to have varied from about £32 to £35. This figure has now risen to from £72 to £80. A really well-stocked cant might easily run over £100. It will be appreciated

that cants yielding a high proportion of hop-pole and pitprop as opposed to cleaving material require considerably less labour.

It should be noted in connexion with the whole of the above section that (*a*) '1939' means pre-war conditions and prices, and (*b*) that sale prices are taken from the books of a fencing company which is believed to be representative, but it is quite possible that some other firms might vary by as much as 5 per cent. either way.

FINANCIAL RETURNS.

In considering finally the financial returns from chestnut coppice one has to be rather careful against coming to hasty conclusions as there are so many factors to be considered not only of supply and demand, but of stocking and quality, and, as has been emphasized earlier, the lie of the land relative to approach by lorry and the presence or absence of standards. In 1944–5 figures of prices realized at auctions received a certain amount of publicity in the national press, figures of from £100 to £130 per acre having been mentioned. Such figures by themselves are misleading, as nothing is said of the 100 or so cants that were sold at the same time or withdrawn at prices of under £20 per acre. Further, some of the specially high prices were known to be the result of antagonism between certain buyers. Another factor, which quite apart from the general rise of prices in war-time, has had the effect of divorcing prices from a real economic basis is E.P.T. Discussing this in connexion with hop-pole prices, le Sueur (5) says, 'Poles bought for renewals can be charged as an outgoing, so that with the present rate of tax the actual cost of poles is not a matter of very great importance.'

The tremendous range in prices at auctions in war-time can best be made clear by taking the results of one sale in November 1944 in Kent. There were 52 lots totalling 94 acres. Of these 22, representing 42 acres, were withdrawn as bidding did not reach the reserve prices. The remainder were sold for the following prices per acre: £135, 100, 65, 50, 3, 32, 75, 67, 10, 7, 21, 28, 21, 10, 9, 11, 11, 20, 26, 25, 33, 11, 49, 53, 16, 10, 19, 40, 50, and 15. This gives an average of £35 per acre. Direct purchases by the Ministry of Supply in 1944 of coppice for preparing 'W.D. Trackway' amounted to over 700 acres at an average cost of £22. 10*s*. 6*d*. and a maximum of £40. This was all bought by private treaty and not by auction and contained considerable areas which the fencing companies would have considered uneconomic, but which had perforce to be worked by the Ministry to meet essential targets.

It is unwise in present circumstances to prophesy about future returns, but it is safe to say that well-stocked pure chestnut coppice reasonably well placed will command prices which offer a really good return on the land utilized.

LITERATURE REFERENCES.

(1) Day, W. R.: *Forestry*, vi. 2, 1932.
(2) Forestry Commission, *Report on Census of Woodlands*, 1924.
(3) Ryle, G. B.: The Coppice Woodlands of South Wales. *Quart. J. For.* xxxix. 2, 1945.
(4) Sueur, A. D. C. le, 'Chestnut Coppice—Planting and Cultivation I.' *Country Life*, 17 Aug. 1945.
(5) —— 'Chestnut Coppice—Planting and Cultivation II.' *Country Life*, 24 Aug. 1945.
(6) Taylor, W. L.: *Forestry*, ii. 1, 1928.

CHARCOAL PRODUCTION

By L. G. T. KENYON

(*Forestry Commission and Ministry of Supply*)

FOREWORD.

THE writer was in charge of charcoal production in the Home Timber Production Department of the Ministry of Supply during the four peak years of the war, when the Department was responsible for approximately one-third of the country's output. He wishes to make it clear that the following notes are based largely on experience within the Department, and do not seek to cover the whole field of charcoal production throughout the British Isles.

Whilst acknowledging with thanks the readiness which the private charcoal producers have always shown to share the details of any new developments in technique, he feels it preferable to confine himself for the most part to departmental practice. It is not to be inferred, however, that the Ministry of Supply accepts any responsibility for the statements or opinions given herein.

By the outbreak of war in 1939, the Forestry Commission had made useful progress in its experimental work with portable steel kilns in the New Forest, but only a handful of these were in use at that time, and a large and rapid expansion became necessary in view of the cessation of imports from abroad. With the best will in the world this could not be accomplished overnight, and it should be placed on record that it was the private charcoal producers who bridged the gap and were largely responsible for maintaining essential supplies of this material in the early stages of the war. The handful of kilns in the New Forest had by the middle of 1943 (the peak period) grown to a total strength of some 400 kilns, scattered in batteries of from 4 to 30 kilns at points as widely separated as Durham and Sussex, and producing upwards of 300 tons of charcoal per week.

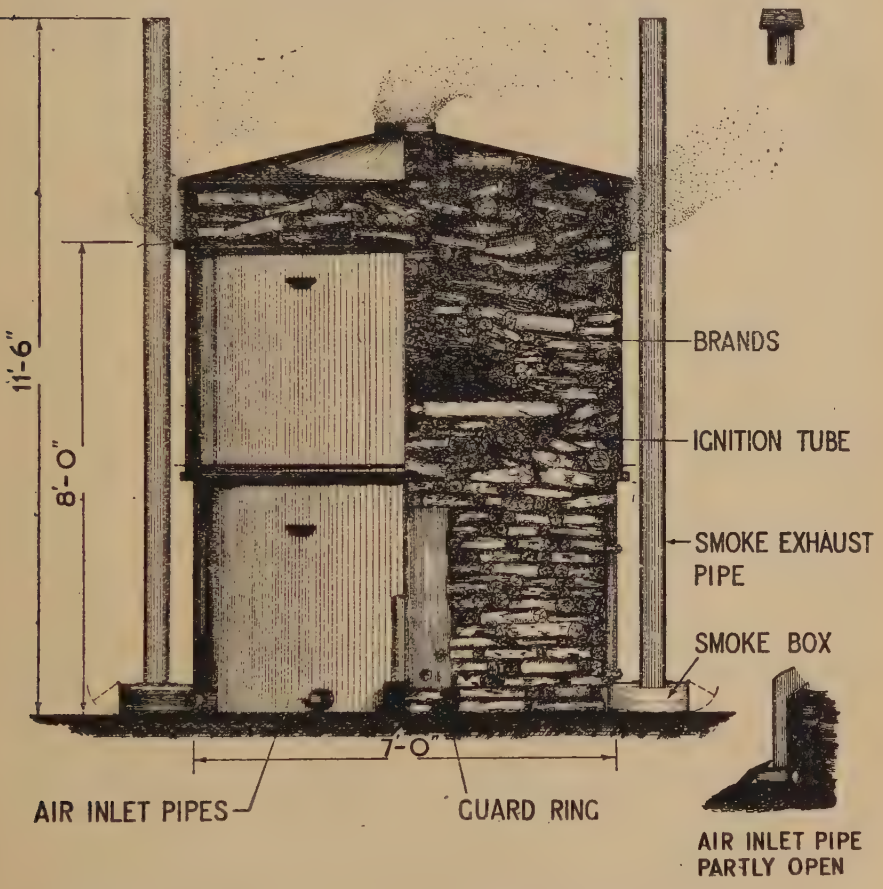
Acknowledgement must also be made to those private producers who helped the Forestry Commission in the matter of kiln design, and to the staff of the Forest Products Research Laboratory who were responsible for the final design of the type of kiln which (with only minor modifications) has given such good service at the batteries operated at the beginning of the war by the Forestry Commission, and subsequently by the Home-Grown Timber Production Department.

TYPES OF KILN.

All charcoal produced by the Department has been burned in circular steel kilns of the portable type. There are several firms in the country who utilize fixed retorts which are externally heated: these have a number of advantages (e.g. the fact that no portion of the charge has to be consumed in the form of fuel), but a disadvantage is that the wood has to be transported over relatively longer distances. In view, therefore, of the anticipated shortage of transport, and of the

amount of labour and material which would have been involved in the construction of fixed retorts, it was decided to concentrate on portable kilns.

The type of kiln used was that designed by the Forest Products Research Laboratory at Princes Risborough, to whom acknowledgement is due for permission to reproduce the sectioned diagram shown below.



Note.—During the past three years the ignition tube has been omitted, because top-lighting is now almost universal.

This kiln is of welded sheet-steel construction, 7 feet in diameter by 8 feet high, and holds approximately 3½ cords of wood. Earlier models were made in three sections, but subsequently a two-section design was adopted which had the advantage of reducing the number of joints (with consequent less risk of air leakage) while still remaining sufficiently portable for all normal requirements.

The conical lid, which has a central opening to accommodate a smaller lid, fits into a channel at the top of the upper section, which itself fits into a similar channel on the bottom section. These joints are sealed with sand to exclude air, and in the case of departmental practice the joint between the top and bottom

sections is kept permanently sealed once the kiln has been erected, as the sections are not dismantled for emptying.

The lower section of the kiln is protected by a perforated inner guard-ring which is intended to prevent distortion and buckling of the kiln through extreme heat. In practice it was found that buckling did occur even with this protection, and to overcome this the most recent models have incorporated bottom sections made from $\frac{1}{4}$-inch steel instead of the original $\frac{1}{8}$-inch thickness, and further stiffening has been achieved by the use of vertical T-section ribs welded to the kiln wall. Another early modification was the suspension of the guard-rings by steel straps hooked over the channel rim at the top of the lower section: this obviated the buckling of the guard-rings which occurred when their bottom edges rested on the air inlet pipes.

Near the base of the lower section are cut four rectangular openings and eight circular ones, the former to take the smoke-boxes and the latter the air inlet pipes. The smoke-boxes are the means of communication between the interior of the kiln and the vertical smoke exhaust pipes, and have also come in for some modification as they were found to be a weak spot as originally designed. In their early form they consisted of a rectangular metal box, open at the bottom and with a central hole in the top to accommodate the smoke exhaust pipe, and it was found that they tended to 'flatten out' owing to the downward pressure of the pipe. Later models were therefore constructed of thicker steel, and had in addition a vertical spigot welded into the top hole, over which the smoke exhaust pipe was a sliding fit. This has made a much stronger job which has stood up well in practice.

Another important modification concerns the method of emptying the kiln. This does not involve any alteration to the kiln itself, but only to the method of mounting it, and is dealt with under 'Emptying' below.

At one or two batteries brick linings were incorporated experimentally in place of the metal guard-rings. These of course prolong the life of the kiln almost indefinitely, but they are expensive to construct and would only be a practical proposition in cases where the kilns can be kept at one site for a number of years. In practice it has been found that the period of cooling is considerably prolonged owing to the greater heat-retention properties of brick as compared with steel.

The Forest Products Research Laboratory has built experimentally a kiln made entirely of brick except for the lid, which is of steel, and this has given quite satisfactory results. It has, however, the disadvantage mentioned above of a prolonged cooling period.

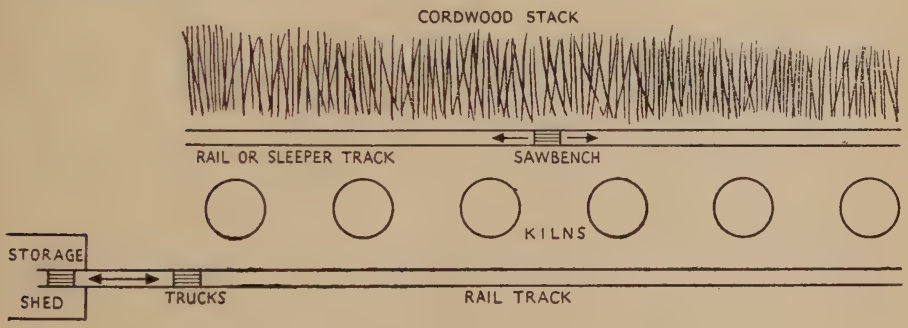
KILN SITES AND LAYOUT OF BATTERIES.

A level and fairly sheltered site should be chosen for the kilns. If the position is too exposed trouble is likely to be experienced due to sudden changes in the strength and direction of the wind—particularly at night when the kilns are usually unattended. It is an advantage to have the site as near as possible to a hard road, so that lorries can collect the charcoal in any weather. A point to watch in this connexion, however, is that kilns should not be installed close to a main road or

any road much used by traffic. The volume of smoke given off immediately after lighting is very considerable, and if blown across a main road may be a source of danger to traffic. A supply of water is essential, and if this is not available from natural sources a storage tank should be installed and kept replenished from the nearest point of supply.

Wherever possible kilns should be operated in batteries of six or more on one site. The number installed must of course depend on circumstances, but only in this way can the various operations be carried out in economic rotation. Theoretically it is possible to burn each kiln three times per week, but in practice it is very often found that two burnings per week is the maximum possible due to interference by bad weather, delays in cooling, &c.

In the light of experience a more or less standardized layout has been adopted for Departmental batteries, as shown in the sketch below:



The kilns are arranged in a straight line, some 10–12 feet apart, with a track (either of rails or sleepers) running the whole length so that the saw bench can be moved up to whichever kiln is being loaded. On the other side of this track the cordwood is stacked: this is handed down in the length to the man at the saw, cut into lengths of 18 inches, and thrown straight into the kiln. On the far side of the kilns is another rail track terminating in the storage shed, into which the bagged charcoal is run in small trucks. (See note on 'Storage' below.) At some of the more permanent batteries an overhead gantry has been built which runs the full length of the line of kilns, and has a pulley over the centre of each to facilitate the removal and replacement of the lids.

SAW BENCHES AND EQUIPMENT.

For all normal requirements a combined engine-cum-saw bench of about 7 horse-power has proved very suitable. This can either be moved on its existing wheels if a sleeper track is used, or mounted on a platform fitted with flanged wheels if a rail track has been installed. In some cases where the wood to be cut is consistently large and heavy, it may be preferable to use a small rip-bench driven by a tractor or diesel engine.

Other smaller items of equipment will be needed—e.g. respirators and goggles for the men emptying the kilns (if this is done from inside), sacks, shovels, ladders, wheelbarrows, tarpaulins, and sand for sealing the kilns.

PREPARATION OF BILLETS.

The cordwood, as mentioned above, can conveniently be cut up on a portable saw bench. Various experiments have been carried out to determine the best length into which the billets should be cut, and—taking into account the important factors of reduction of loading time and loading to capacity—18 inches has been found a very satisfactory length. It is undesirable to put into the kiln billets of either too large or too small diameter, as the former will not carbonize fully while the latter will be burnt to ashes. Eight inches should be regarded as a maximum (pieces over this size being split before loading), and 2 inches as a minimum.

METHOD OF LOADING AND LIGHTING.

It has been established by experiments that it is a waste of time to try to stack or arrange the wood within the kiln. To achieve speed of loading combined with satisfactory yields it is best to throw the billets into the kiln straight off the saw, with the proviso that if the material to be burned varies widely in size it is preferable to have the larger pieces at the bottom and the smaller at the top. The kiln should always be 'over-filled' to as much as a foot above the level of the top rim, as during the first stages of burning the wood will settle into the kiln and be just about level with the top when the time comes to seal down the lid. The latter should be perched on top of the charge before lighting, and—with a little adjustment—it will settle into its channel as the wood packs down.

Where it is proposed to light the charge at the bottom, a bed of kindling material (consisting of 'brands' and pieces of dry wood) should be laid centrally at the bottom of the kiln before loading commences. This should be well soaked in paraffin and protected by a carefully arranged stack of billets, and a tunnel should be built of billets laid radially from the kindling material to one of the air inlet pipe openings. When loading is completed a rag soaked in paraffin is lit and pushed down the tunnel on the end of a stick.

Where the charge is to be lit from the top, the bed of kindling material should be laid about three-quarters of the way up the kiln, and the tunnel should be built vertically to connect the kindling with the central opening in the lid. It has been found convenient for this purpose to use a length of chimney, placed upright on the kindling and withdrawn when the remainder of the charge has been stacked round it. Lighting is effected as described above, the flaming rag being inserted through the central opening in the lid.

There is little doubt that lighting from the top is the better method, though some burners contend otherwise. It avoids the crushing of the charcoal at the bottom of the kiln, which of course is carbonized first when the kiln is lit from below, and the incomplete carbonization of the wood at the top.

BURNING.

At the time of lighting both the air inlet pipes and the smoke-boxes are closed with the damper-plates provided. Thus air can enter only through the space between the lid and the top rim, and this prevents too fierce a burning in the first stages and helps to spread the fire and draw it upwards from the kindling. The

warming-up process is continued for from half an hour to perhaps an hour and a half, depending on whether seasoned or fresh wood is being used, and during this period dense volumes of smoke pour out from under the lid while the latter gradually settles into place. A period of fiercer burning, normally of about the same duration as allowed for the warming-up process, is next initiated by opening the air inlet pipes to about half their effective aperture. When the smoke issuing from the top becomes noticeably less in volume, and changes in colour from dirty white to pale blue, the lid should be sealed into its channel, the small centre lid placed in position and likewise sealed, the smoke-boxes opened, and the smoke exhaust pipes erected. This has the effect of reversing the draught, and the kiln is now at a stage where it can be left for steady carbonization to proceed. Assuming that it has been lit at about 2 or 3 o'clock in the afternoon (which is the most suitable time), it can now be left for the night without much fear of attention being required until the next day. The amount of damping needed will depend on whether the wood is fresh or seasoned and on the strength of the wind, and the correct settings for different conditions can only be learnt by experience.

On inspection the following morning it may be found that the charge has burned unevenly—i.e. that carbonization is more advanced on one side of the kiln than on the other. This can be checked by the colour of the smoke issuing from individual smoke exhaust pipes, a pale blue colour indicating that carbonization is complete and that charcoal is being burnt. Another method of assessing the progress of carbonization is by the 'water-test': if water thrown against the kiln surface close to the ground evaporates instantaneously, it indicates that carbonization is complete at that point.

When observation of the smoke and the water-test confirm that carbonization is completed in one section but not in others, the air inlet pipes should be sealed off in the former (with the damper-plates provided) and opened fully in the latter, while those smoke exhaust pipes which are emitting pale blue smoke should also be closed. When pale blue smoke is seen to be coming from *all* the smoke exhaust pipes it is a sign that carbonization is complete throughout the kiln, and the latter should then be thoroughly sealed so that all air is excluded. The smoke exhaust pipes are taken down, and the smoke-boxes and air inlet pipes closed with the damper-plates, and sand is then heaped around the base of the kiln to a point well above the openings and patted firmly into position with the back of a shovel. It is most important that this sealing should be thoroughly carried out, as the smallest air leak may permit a portion of the charcoal to remain 'alive', with the result that when the kiln is opened the fire will spread rapidly, charcoal will be lost, and water will have to be used (to the detriment of the charcoal) to extinguish the blaze. When sealing is being carried out, therefore, it is desirable to check up on the joints between the small lid and main lid, the main lid and top section, and the top section and bottom section.

The normal period for completion of carbonization is 24 hours from the time of lighting, but there can be no hard-and-fast rule about this as the time taken will vary according to circumstances. Similarly the period required for cooling is normally 24 hours from the time of sealing, but here again the period may be

prolonged by, for instance, a small air leak which has escaped detection. It is, therefore, advisable to feel the kiln surface to make sure that it is stone cold before opening up.

EMPTYING.

It has never been the practice at the Department's batteries to dismantle the kilns for emptying, as is done by some other producers, but instead the method has been for the men to climb inside the kilns and fill the sacks there. This is not a very pleasant process, even with the use of the respirators and goggles which are provided at all batteries, and it has accordingly been superseded (at those batteries where the kilns were to remain on one site long enough to justify the outlay) by a method which permits the kilns to be emptied from the outside. To achieve this the kilns are mounted on a brick or concrete base about 1 foot thick, and this incorporates an emptying 'chute' about 3 feet long by 2 feet wide which slopes from the centre of the kiln base down to ground level. This is covered during loading, burning, and cooling by a steel tray, which is slid out when the kiln is ready to be emptied, thus allowing the charcoal to be raked out from outside and bagged up with shovels. A useful accessory in this process is a stand to which the sack can be hooked so that it is held open for filling, thus enabling one man instead of two to do the job.

YIELDS.

The yields of charcoal obtained vary considerably according to the type and moisture-content of the wood being burned. Beech as a general rule will give higher yields than oak, while softwoods such as pine and larch give a considerably lower yield than hardwoods. Well-seasoned wood will always give better results than wood which is freshly cut, as in the latter case a greater proportion of the charge is inevitably consumed in the form of fuel. The average yield throughout the Department's batteries has probably worked out at between 1,200 and 1,300 lb. per kiln burned: exceptional yields of as much as 1,800 lb. have been recorded where conditions and type of wood were ideal.

GRADING.

In the case of charcoal required for carbon bisulphide manufacture, it was necessary to screen off all dust and material below $\frac{1}{2}$ inch, and for this purpose an ordinary potato grader, fitted with the correct size of mesh and slightly modified in detail, has proved very satisfactory. The type used has a screen which is oscillated by turning a handle, and an elevator which carries the larger charcoal upwards and delivers it automatically into a sack suspended underneath. At some of the larger batteries a more ambitious type of machine was used which was motor-driven and incorporated a cyclone fan to extract the dust: it delivered the charcoal in three different size-ranges. This machine was used to produce charcoal of the correct size for burning in the producer-gas lorries, of which the Department employed quite a number. For this purpose it is important that the charcoal should be free from dust and within a size-range of about $\frac{1}{2}$–$1\frac{1}{4}$ inches.

STORAGE AND FIRE PRECAUTIONS.

Charcoal is a bulky and difficult material to store, and it is necessary to have a storage shed of ample size at the battery. This should incorporate some type of flooring to keep the bags clear of the ground, and—while being as waterproof as possible—should be well ventilated.

Charcoal is liable to spontaneous combustion, and if by oversight a bag containing some 'live' material is placed in the storage shed a disastrous fire may ensue. For this reason it is a firm rule at all the Department's batteries that no charcoal shall be placed in the storage shed until it has been stored under a tarpaulin for at least 24 hours after emptying, as with this precaution any fire which may occur can be quickly dealt with, and loss is minimized.

The railway companies make a rule that no charcoal may be loaded on rail within 4 days from the time at which it was unloaded from the kiln.

LABOUR.

Skilled labour is not essential for charcoal production provided there is a man in charge with the necessary knowledge to supervise the lighting and tending. For batteries of six kilns or more it has been found that one man per two kilns provides the correct labour strength for efficient and economic management.

SPECIES OF WOOD.

It cannot be said that charcoal made from one species is 'better' than that made from another, as the various species produce charcoal of which the characteristics make it suitable for some purposes and unsuitable for others. For carbon bisulphide manufacture, for example, the charcoal is required to be *chemically* reactive (as distinct from *physically* reactive), and for this purpose beech, birch, hornbeam, chestnut, holly, and alder have all been found satisfactory. Amongst these species beech, birch and hornbeam, in particular, have the added advantage that they do not readily break down into dust. Oak, ash and elm, while not satisfactory for carbon bisulphide, have proved quite suitable for purposes such as case-hardening, though the last-named is not much favoured owing to the high ash content resulting from its thick bark. Alder and alder buckthorn, in particular, have been in demand for explosives, willow for medicinal purposes and (in peace-time) artists' crayons, and softwoods (e.g. pine and larch) for penicillin production and navigational lighting. For use as fuel in producer-gas vehicles, strong charcoals such as those made from beech, birch and hornbeam are favoured as they produce the minimum of dust.

USES OF CHARCOAL.

During the war the three most important uses to which charcoal has been put were probably (*a*) carbon bisulphide (for smoke screens and other devices of chemical warfare, and for rayon), (*b*) case-hardening (aero-engine parts, motors of all types, gear-wheels, tank and lorry parts, &c.), and (*c*) explosives. An interesting development which has come into prominence during the last few months is the use of charcoal as a filtering and storage agent in the process of penicillin

production. For this purpose the charcoal is 'activated' by steam pressure, and tests so far carried out show that softwood charcoal is particularly suitable.

Other uses of charcoal may be briefly listed as follows: animal and poultry foods, filtration, fuel (smokeless cooking, &c.), gas masks, horticulture (lawns, soil aeration, &c.), insulation (cold storage, &c.), medicinal purposes, navigational lighting, paint manufacture, producer gas, smelting, welding.

CONCLUSION.

It can fairly be said that charcoal is a 'munition of war', and all credit is due to the industry for having maintained, under by no means easy conditions, the supplies which were so urgently required, and to the men who worked long hours at the kilns in the execution of their dirty and exacting jobs. Let us hope that a prosperous future lies ahead of them now that their products are being turned to the saving of men's lives instead of their destruction.

THE UTILIZATION OF ALDER BUCKTHORN

By F. G. O. PEARSON

(*Forestry Commission and Ministry of Supply*)

ALDER buckthorn, *Frangula alnus* Miller (*Rhamnus frangula* L.), like many other commodities, played an important part in the war effort that was known to few people.

This shrub, growing to 20 feet in height and 6 inches in diameter (but usually not larger than 6 to 8 feet in height and 1 to 2 inches in diameter), is found in the United Kingdom from Dumfries-shire southwards, but is absent in certain counties.[1] It is not confined to the British Isles but is widely distributed on the Continent. It is found on various types of soil, such as the fen peat, the light acid sandy or gravelly soils, the clays, and the low-lying drained lands. The shrub does not grow in large quantities except in a few places such as Wicken Fen in Cambridgeshire, but is usually found in small scattered clumps.

The importance of the shrub is twofold. Its most important use is as a raw material for the making of special charcoal used in the manufacture of munitions, and secondly the bark and berries have a value for the preparation of purgatives.

Prior to 1937 the supply of alder buckthorn was obtained mainly from the Continent, but with the political situation deteriorating, inquiries were put in hand as to the supply in this country. A quantity large enough to meet the country's peace-time demands was found in the New Forest and the Wicken Fen. In 1938 the first cutting and preparing of this material was undertaken by the Forestry Commission in the New Forest, and this went on throughout that year and the following. With the outbreak of war in 1939 it became necessary to step up the production considerably, and the information gained prior to the war proved useful. The material is supplied in the round for the preparation of charcoal, but must be absolutely free of bark. It is usually cut in 2½-foot lengths, and when peeled it is tied in bundles large enough to be easily handled. If the material is cut in the spring and peeled immediately, there is no necessity for any other treatment as the bark comes off easily. Owing to the quantity required during the war and with the limited amount of labour, it was found necessary to boil before peeling to enable the preparation to continue throughout the year. It was found that as the shrub grew in scattered places, it was advantageous to do all preparation at central depots and to collect the material from the surrounding district.

Girls of the Women's Timber Corps were specially trained for searching and locating the shrub. When a suitable area was found an arrangement was made with the owner, usually to pay a royalty of an agreed price per ton for all the

[1] '*Frangula alnus Miller* (*Rhamnus frangula* L.)', by H. Godwin, *Journ. of Ecol.* xxxi. 1943, pp. 77–92.

material removed from his land. Cutters were then sent to the site and supervised by the girls to see that only *Frangula alnus* was cut. The cutters felled and cut to length all material over half an inch diameter under bark. This was then bundled and brought into the depot by lorry. At the depot there were built a number of boiling coppers which could be heated with a fire below, and sheds open one side with benches round for the workers to sit on while doing the peeling. There was one shed for drying the bark, one for storing the peeled material, and an office hut for keeping records. The wood on being received at the depot was weighed and a note made of the weight and the place it came from so that the royalty could be paid. It was then distributed among the huts. The wood was first placed in the coppers and boiled for between half an hour and an hour. It was then lifted out and the bark scraped off with a dull knife. Whilst this was done another charge was being boiled so that the peelers were kept constantly at work. When all the bark had been removed the wood was laid out to dry, which took from 2 to 3 days, depending on the time of year. It was then put into bundles of approximately 40 lb. and weighed again. This is the weight on which the peelers are paid and by which the material is sold. The bundles were labelled, giving the weight of each bundle, and stacked on skids clear of the ground. When a railway wagon load was ready the material was immediately consigned against orders.

In 1940 the second use was considered—that is the use of the bark for preparation of purgatives. There is nothing new in this, because for centuries gipsies have eaten the berries or chewed the bark of alder buckthorn as a purgative. I have been told by the gipsies in the New Forest that the berries are much stronger than the bark. Bark stripped in the spring without boiling is better than the boiled bark, as the boiling destroys the purgative properties of the bark. The bark when stripped is taken to the drying-tent, but on no account must the bark be left in the sacks or it will soon heat and in a very short period deteriorate to useless. The drying was done in a very crude manner. In the drying-tent there was a rack made of galvanized sheets with an oil stove below to supply the heat. This required constant supervision to see that the bark did not scorch or dry too quickly, and it was necessary to turn it constantly. It would have been better to have air-dried it on wire trays, but it would have meant an extensive shed as the process would have been very slow, especially in winter. When thoroughly dry the bark was packed in clean, dry sacks for dispatch.

At the commencement of the search for the shrub use was made of the services of local botanists, geological maps, and books on country flora, but the Biology War Committee made a most excellent survey which facilitated the task of the searchers and enabled the authorities to know the approximate quantity they had in reserve.

THE PREFERENCE SHOWN BY BIRDS FOR DIFFERENT SPECIES OF TREES IN PLANTATIONS

By J. M. D. MACKENZIE

(*Indian Forest Service, Retd.*)

IT has been found that in plantations birds nesting off the ground and not in holes, that is the thicket and most hedgerow birds, show a definite preference for certain species of trees. It is thought that the facts already known are of sufficient interest to warrant publication, although the investigation is not complete.

There is a strip planted as a windbreak at Tullach Ard, Perthshire, which consists of a number of small blocks of trees of various species. It is now 15 years old, of medium quality, and fairly even growth. The willows are 35 feet high, the hybrid larch and alder 30, Sitka spruce 30, Scots pine 20, Norway spruce about 18. During the last 4 or 5 years, first the larch, then the Scots pine, and finally the spruces have been brushed up, mainly by the writer. Over the last 10 years it has always contained a high number of nests, but these were thought of as just 'in the strip' until the beginning of this year, when it was noticed that the nests were almost entirely in the Sitka spruce. We are not very proud of the time it took us to grasp this fact, but the blocks are intimately mixed, and until recently one was never in any one species for more than a few yards at a time. This year the brushing up of the Sitka was completed, and this happened to coincide with considerable shedding of needles, which made it much easier to see into the trees. A careful count was made of all nests which could be seen, old and new, and this made it clear that in spite of the intimate mixture of blocks, the great majority of the nests were in the Sitka, with a few in Norway spruce, and for all practical purposes, none in the larch, Scots pine, willows, alder, &c. This led to an examination of other woods, and on the whole they agree with the Tullach Ard strip.

There does not seem to be any marked preference for any one tree species except for nesting, that is, one sees birds moving about in plantations of all species in nearly equal numbers if the fact that there are most nests in spruce is discounted. Wherever they feed, birds will be seen most often near the nest. The matter needs to be further checked, but at least the preference for certain species for nesting is not repeated when it comes to feeding, and probably in plantations there is little preference at all, numbers being governed by food-supplies. It also remains to be seen whether there is any preference for particular species in sites for nest-boxes; there has been no opportunity for finding out about this. Except where otherwise stated, all nests referred to below are those in trees, and not on the ground or in holes.

METHODS.

The Tullach Ard strip, in which the first nest counts were made, is L-shaped, running north-east and south-east from the angle. It is about 700 yards long, and nearly all 12 rows wide, 6 rows being Sitka spruce and 6 other species. All trees except the willow and alder are planted 4 by 4 feet. It was 14 years old when

counts were made, and is specially suited for such counts because it is brushed up to 7 feet, so one can see and move about in it, growth is fairly even, and the writer planted it, and has had it under constant observation ever since. There was a period between about the 8th and 12th years when it was so thick that one could only force a way into it with considerable trouble, but even then it was possible to see in from the sides. In brushing it up to 7 feet, the first 7 years' branches, more or less, have been removed, leaving at the time of counting 7 years' branches on the tree. As there is no cover for them, nests are rarely, if ever, found in the youngest 3 years' growth, that is, in May, the shoot of the year before and the 2 years before that. So nests counted are almost certainly those of the last 4 years only. There may have been some in the branches removed, in fact there probably were, but on the whole the figures are nearly correct, being, if anything, low.

The age of an old nest in young plantations can be very nearly fixed. If it is in the sixth whorl of branches from the top, remembering that there are no nests in the top three whorls, it must be 3 years old or less. If it is not this year's nest, it must be either 2 or 3 years old. It cannot be more as that part of the tree was not there at all 6 years ago. It is difficult to tell the age by looking at it: needles and leaves in the cup help and so does the colour of the materials; but moss may stay green for at least a year. Blackbirds' (*Turdus merula*) and thrushes' (*Turdus ericetorum*) nests last very well, old nests being sometimes used as platforms for new. But the flimsier ones, dunnocks' (hedge-sparrow; *Prunella modularis*), yellow buntings' (*Emberiza citrinella*), &c., are often left in a very flattened and dilapidated condition when the nestlings have flown, and may appear to be in the last stages of disintegration. Two dunnocks' and a yellow bunting's nests were marked down for examination. As soon as the nestlings had flown, two of them were reduced to a sort of pad, with the appearance of having been trampled flat, and would have been put as 3 years old with justification, while the third was in quite good shape. A chaffinch's (*Fringilla coelebs*) nest which had been disturbed was absolutely and entirely removed in a week. There may be other similar disappearances, so the number of nests found is a minimum for 4 years. As noted above, there will certainly be other nests which have not been counted as, 4 years ago, what is now the seventh whorl would have been the fourth, and so only just within the nesting-level. It is known that there were nests at this time, and some at least will have been in the whorls which have been removed in brushing up. This proportion of nests removed will decrease each year and will to some extent be balanced by nests at lower levels in the edge trees, where branches have been left to keep out the wind. Most nests except stick nests such as a wood-pigeon's (*Columba palumbus*) only last 4 years, although this wants checking. The number given is a minimum, and this point is made because the number of nests found is very high, even for an island site (about 75 per acre per annum, in trees only). See Appendix No. 1*a*. See also Nos. 12 (*e*), 28 (*c*), and 32 (*c*).

As regards normal populations, Elton (4) quotes Palmgren as recording from Finland 1,060 birds per square kilometre, in mixed woodland with scrub as against 400 in mixed conifers, figures which correspond to about 2,600 and 1,000

per square mile, or roughly 4 and 1½ per acre. Colquhoun (2) records 80 redstarts (*Phoenicurus phoenicurus*) and 62 robins (*Erithacus rubecula*) from 3,000 acres of Savernake Forest, in addition to other birds. An island site, such as the strip, contains almost all the nests for a feeding area of anything up to 100 acres.

In other woods a method has been developed from the above. Areas with two or more species planted pure and adjoining each other are selected, conditions being as nearly as possible the same in each species, that is planting distance, degree of success, treatment including thinning and/or brushing up, and, as far as may be, surroundings. For instance, a cottage with a garden, or fields and farm buildings, within 200 or 300 yards improve the species nearest as a nesting site. Plots, which need not be marked out, but can be judged by the number of trees counted, are taken on each side of the boundary between the two species, and all nests seen in them are counted, being classed into big (hawks, crow (*Corvus* spp.) &c.), medium (blackbird, thrush), and small, wood-pigeons' nests being omitted. The numbers in each plot show the popularity of that species relative to the other. A series of such pairs with different species give a link up amongst themselves and allow of the species being placed in order of popularity. Thus 3 pairs of species, *A* and *B*, *C* and *D*, and *E* and *F*, only show the relative popularity of each pair. But if we can find pairs of *A* and *C*, *B* and *D*, *A* and *E*, *C* and *F*, &c., it is possible to make a fairly definite list. The absolute numbers in any given pair can only be used for that pair, as outside influences govern the number of birds nesting in any site, while they are eliminated as between two species growing alongside each other. Thus in the strip at Tullach Ard there are 14 nests per 100 trees in Sitka spruce, and 8 in Norway. This does not even mean that Sitka is about twice as popular as Norway spruce, as the most popular species tends to attract to itself by far the greater number of nests. If the whole plantation were Norway spruce, it would contain nearly as many nests as it actually does, and if it were all Sitka spruce, it would only contain a few more. An endeavour has been made to show this in the following table, where the total area is the same in each line; the most popular species in each line is omitted in the following one, so that in the first line each species is one-sixth of the area, in the second one-fifth, in the third one-quarter, and so on. The actual figures are entirely hypothetical, serving only to show what might be expected from experience; that is the decrease in total nests in the area in the absence of the most popular species, the increase in nests in the remainder, but especially in the species next in popularity to the one removed, and the heavy decrease in total nests when only the least popular species are left.

Sitka spruce	*Norway spruce*	*Cypress*	*Scots pine*	*Larch*	*Ash*	*Total*
70	20	7	2	1	0	100
..	50	15	5	2	0	72
..	..	35	8	3	1	47
..	..	..	20	4	1	25
..	..	..	..	16	2	18
..	..	..	..	..	8	8

In the garden at Tullach Ard there are single trees and hedges which would ordinarily hold nests, but because of the Sitka in the strip, there are very few, at times none in them. There is a plantation of about half an acre just over the march, joining one end of the strip, and containing Scots pine, Norway spruce, and larch mixed by rows. In the first year or two after the strip was planted, when it was still very small, this was full of nests. No counts were made, but it was noted as containing more nests than any similar plot know to us, nearly all being in the Norway spruce. It now contains practically no new nests, and the birds have all moved into the Sitka spruce in the strip.

Where equal numbers of trees cannot be obtained, as in plots Nos. 3, 4, 5, and 12, nests are reduced to some common proportion, e.g. per 100 or per 1,000 trees. It is probably impossible to get an exact figure representing popularity, but an approximation is enough for our purpose. Differences of age and density can be adjusted, but the ideal method remains to find pairs where no adjustment is needed, except where small intrusive patches are chosen deliberately.

DIFFICULTIES.

It is a regrettable fact that work done under awkward or uncomfortable conditions is often bad, so it is advisable to select a dry day, and plantations which have been brushed up.

Outside factors have to be watched. At Tullach Ard, birds nesting in the strip feed in plantations up to at least 400 yards away. So gardens, farm buildings, rubbish dumps, &c., may affect the nests in a plantation up to this distance away, and they will affect the species nearest to them more than the one farther away. Small woods and wood edges are affected by the fields round them, and by the crops grown, and so may be affected differently from year to year. Like the average man, the average wood is a concept which probably does not exist, particularly as a nesting site, when not only the wood but its surroundings have to be taken into account. Divergences from the normal have to be be allowed for.

Seeing nests at all in the tops of, for example, cypress and spruce is difficult, and shells of hatched eggs have been seen on the ground when it was impossible to find the nests from which they came. This applies especially to new nests. A census in spring might help, as singing-birds can then be heard.

Even counting trees presents difficulties. The ideal is to mark out plots and number the trees, but this is a long job, and probably only necessary in special cases. The method employed has been to walk through a wood and count the rows passed. In spruces, &c., one can see into either 2 or 3 trees on either side of the path followed, that is 4 or 6 trees in each row, which means that 25 or 16 rows give 100 trees examined. In trees such as Scots pine or larch, 5 trees on either side can be seen, and this means that each 10 rows passed give 100 trees. The method is rough, but gives sufficiently accurate results for a count of nests.

Another problem is what trees to count; this arises in young plantations where growth is uneven, and still more in comparing young plantations with those a few years older, e.g. No. 12, *c* and *e*. At 21 years old Scots pine are either definitely trees to be counted or dead. At 12 years Sitka spruce may vary from a well-grown

bushy tree 15 or 20 feet high to a wretched little thing, 2 feet, with very sparse foliage in which no self-respecting bird would nest at all. Actually, in such plantations most of the nests are found in fair to good trees, but not in the very biggest, which are usually rather open and stick out above the general level. If one is dealing with acreage, the point does not arise, but with numbers small trees which are impossible for nesting have been omitted, like trees removed in thinnings or dead. But suppressed trees in plantations with a closed canopy should be included, as, e.g., dunnocks use them.

Silvicultural treatment has to be taken into account. Brushing up and pruning remove branches, and so the nests in them, and change the character of the wood. Thinning removes possible nest sites, and again changes the character of the wood by making it more open. The exact effect of such operations has not yet been fully studied, although Lack (7) says of the Breckland Scots pine that the dead lower branches simulate ground cover for the whitethroat (*Sylvia communis*), wren (*T. troglodytes*), and dunnock which tend to disappear when the trees are brushed up.

Nests can be counted in winter, and this is the best time for deciduous species.

EXPRESSION OF RESULTS.

It has been difficult to find a way of recording counts, of which some 120 have been made up to date. The figures alone, without full data, are not very informative and may be misleading. For plantations up to 20 years old which have not been thinned, nests per 100 or per 1,000 trees give comparable figures, provided the original spacing was the same and growth has been fairly even. But after the first thinning, when up to 50 per cent. of the original trees may be removed and the numbers left (according to the Forestry Commission's yield tables (5)) vary considerably with both species and quality class, this method is not suitable except as between plantations with similar numbers of trees per acre. One thousand trees may occupy anything from one-fifth of an acre with 3 feet spacing to five-sixths with 6 feet, and 2 acres with 30-year-old Japanese larch and Sitka spruce. Particularly when studies extend to older woods, it is thought that acreage will be the most convenient all-round criterion, and that the best unit, at once small enough to handle and big enough to show differences where totals may only run to one or two nests per acre, will be 10 acres. Accordingly results have been reduced to nests per 10 acres where possible. If the spacing is known, counts per 100 and per 1,000 trees in younger woods can easily be expanded to this figure.

BIRD CENSUS.

Counting the birds in a given area is not a very easy thing to do. Existing censuses have been made in several ways, some at least of which are such that after consultation with those who carried them out it is not thought possible to reduce the figures to an acreage basis. They serve well to compare one area with another, both worked in the same way, or to give an idea of the bird population in any given type of wood. This will be best understood from a brief description of three methods.

(*a*) *Nest Count.* In the spring all nests in a given area are found. This gives nesting-birds but omits others, and is only applicable to very small areas.

(*b*) *Mapping.* In spring all singing birds (males) are counted and mapped. By repeating two or three times at intervals, and adjusting the map, most males are included. This method only includes males, and some of them may not have mates or nests. In both the above the area *may* be known, and the figures reduced to an area basis.

(*c*) *The Sample Count.* The observer walks through woods at a given pace, usually 1 mile an hour, for a given time, usually an hour, and notes all birds seen and heard. Figures give comparative populations, but it is impossible to reduce them to numbers per acre, as visual and auditory records cover different areas for different birds. For instance, Nicholson (10) says he can hear a goldcrest (*R. regulus*) at 70 yards, a willow warbler (*Phylloscopus trochilus*) at 200, a chiff-chaff (*Phylloscopus collybita*) at 300, a corn-bunting (*Emberiza callandra*) at more than a quarter of a mile, a blackbird at half a mile, and a bittern (*Botaurus stellaris*) at 2 miles, under favourable conditions. One may see or hear the same bird more than once, and Colquhoun (1), dealing with the relative conspicuousness of various birds, shows that certain species are much more easily and more frequently missed than others. This is especially the case outside the breeding-season, a time at which males court observation. Quite a large wood is required, and many of our woods are under 100 acres in extent. It would be impossible to apply, e.g., to cypress or *Thuya* plantations, as there are none big enough, but an adaptation may be worked out. It is a good method for getting comparative figures quickly.

For a comparison between the populations in an area before and after putting up nest-boxes or taking any other step to attract birds, mapping singing males appears to be the most suitable. This is not known to have been done yet.

BIRD SPECIES.

Some birds are found almost entirely in certain woods, for instance those classic examples, the Scottish crested tit (*Parus cristatus scoticus*) and the capercailzie (*Tetrao urogallus*) amongst old Scots pines, the one becoming almost extinct owing to the curtailment of its habitat, the other disappearing altogether and being reintroduced successfully when extensive replanting took place. Also the crossbill (*Loxia curvirostra*) amongst pines. Colonel Maitland of Burnside, Angus, tells me he had numerous crossbills every winter in some 50 acres of *Pinus montana* feeding on its prolific cones, but that since they have been felled none have been seen. The nuthatch (*Sitta europoea*), marsh tit (*Parus palustris*), and nightingale (*Luscinia megarhyncha*) amongst others are found almost exclusively in broad-leaved woods. Lack and Venables (8) go into this fully.

The requirements of birds for a nest site are difficult to explain. There may be plenty of sites in which a willow warbler or a tree pipit could make their nests, but unless they have a suitable song-post near by, they will not use them. The tree pipit does not even use the post to sing from: it sings in the air, but must have a post to return to after its song has finished. In places the removal of

hedges has caused the disappearance of certain birds by depriving them of song-posts, and the arrival of electric pylons and telegraph poles has brought about their reappearance. Entirely unreasonable, but there it is; in the same way certain perfectly good dress materials will not sell just because they are not fashionable.

Birds breeding in holes will not nest in young plantations where there are none, although they feed in them (tits, nuthatch, woodpeckers (*Picidae*)). But coal tits (*Parus ater*) nest in boxes near the ground in young conifer plantations (Lack (6)). Some birds want a song-post near the nest, each species having a particular height which it favours: others must have low cover or undergrowth. In the Breckland Scots pine plantations, Lack (6, 7) found stonechats (*Saxicola torquata*) and whinchats (*Saxicola rubetra*) increased up to the 4th or 5th year, and then disappeared. They want a post about 3 feet high. The willow warbler wants one about 5 feet or more, and appears about the 4th year, becoming the commonest species from the 7th to 12th years, when it decreases again as the undergrowth dies out. The whitethroat and wren are fairly common from the 5th to the 12th year, but decrease when the plantations are brushed up. The dunnock appears a bit later, but is otherwise similar. Goldcrests and chaffinches appear about the 8th year, and the blackbird and thrush about the 6th and 7th. The coal tit appears about the same time as the chaffinch and goldcrest. The tree pipit (*Anthus trivialis*) disappears about the 10th year, but with the woodlark (*Lullula arborea*) reappears about the 15th, after brushing up gives a clear space. It requires at least one fair-sized tree near the nest.

Plantations at Tullach Ard are in fairly close agreement with these dates, except that no birds nested in the Scots pine or larch, and a few in the Norway spruce, mostly thrushes and blackbirds, the rest being in Sitka spruce. Coal tits have not yet appeared, but boxes have not been put up for them. Stonechats and whinchats are absent, willow warblers appeared about the 3rd year, but were singing from willow sets. Dunnocks appeared early, but were nesting in gorse bushes. Goldcrests have not appeared at all, and chaffinches came about the 7th year. We have had numerous greenfinches' (*C. chloris*) nests since about the 6th year, wood-pigeon since about the 10th, and an occasional garden warbler (*Sylvia borin*). Yellow buntings are common on the edges, but nest actually in the lower branches of trees up to about 4 or 5 years old, and later in widely spaced larch where, however, they nest in rubbish on the ground.

In addition to 5 willow warblers, 4 yellow buntings, and a robin noted singing, we found in the first week of May the following 33 occupied nests. The numbers in brackets give the whorls in which they were situated, counting the shoot of the year before as number 1.

Wood-pigeon	2 (5, 7)
Blackbird	4 (3, 4, 5, 5)
Song-thrush	3 (4, 6, 6)
Chaffinch	7 (4, 4, 4, 5, 5, 6, 7)
Greenfinch	10 (4, 4, 4, 4, 4, 5, 6, 6, 6, 7)
Dunnock	5 (3, 4, 5, 5, 6)
Unidentified	2 (4, 5)

The two nests in whorl 3 were in suppressed trees, the level being that of the normal 5 or 6. The unidentified nests were small and may have been goldcrests. They could not be reached, and it was not realized at the time that anything but numbers was wanted. Birds slipping away in the tops of a Sitka plantation may be almost impossible to see properly. In addition, a number of nests, possibly second broods, were found later, and, considering the difficulty of seeing new nests at all, the number is thought to correspond fairly well with the average of previous years. No special effort was made to find all nests for a census.

The main species concerned in the present nest counts, besides those listed above, are an occasional redpoll (*Carduelis flammea*), blackcap (*Sylvia atricapilla*), garden warbler, bullfinch (*P. pyrrhula*), long-tailed tit (*Ægithalos caudatus*), wren, yellow bunting, goldcrest, whitethroat, and possibly others.

THE AVERAGE OR NORMAL WOOD.

Certain birds are called woodland species, but few live exclusively in woods. Lack and Venables (8) say '. . . the general impression gained is that the woodland bird "community" is extremely loosely knit; most of the species are by no means confined to woods . . .', and this is perhaps partly because few woods are homogeneous. A wood is an agglomeration of conditions, and while we can recognize general types, it is almost if not quite impossible to find any two areas which are exactly alike—the cause of much of the difficulty in selecting all sample plots. Plantations when young tend to approximate to each other more closely than older woods, because outside factors have not been acting on them so long, but some of the features, apart from tree species, in which they differ from a bird's point of view are age and quality class, representing height, bushiness, foliage, and space between branches; gaps, where undergrowth changes; methods and degree of thinning and pruning; undergrowth; game preservation and its effects, especially on stoats, weasels (*Mustelinae*), squirrels (*Sciurus*), jays, magpies (*Corvidae*), and hawks (*Raptores*); supply of nesting materials; the proportion to the whole of edges, streams, rides and roads, firelines, intruding species, banks, rocks, and dikes; patches where the growth is over and under average; the presence of felling refuse, especially old stumps; and the surroundings up to 400 yards. To take edges as an example, if we include the outer 25 yards as 'edge', in a wood a mile square 7·5 per cent. of the total area, or 36 acres, is 'edge wood'. Rides, roads, and firelines often come to about the same, and each of these has its own avifauna, differing somewhat from that of the wood proper.

Even in good plantations, one comes across places where, facing one way, the picture is a good wood, while facing the other, it is anything from understocking to a sheer blank. Generalities are always dangerous, but it is fairly safe to say that there is no such thing as either the absolutely normal wood, that is just what the forester wants, or the average wood, implying an exact mean of all conditions.

THE WOODLAND BIRD COMMUNITY.

There is also probably no such thing as the normal woodland bird community. The bird population of a wood of any size is made up of ordinary 'woodland

birds (tits, nuthatch, woodpeckers, some warblers, chaffinch, blackbird, goldcrest, &c.), birds which use secondary growth (long-tailed tit, nightingale, pheasant (*Phasianus colchicus*), birds using rides, roads, and blanks (willow warbler, garden warbler, dunnock, tree pipit, and in big blanks even birds of the open heath and grasslands), wagtails (*Motacilla* spp.), &c., along streams, birds of the edges (yellow bunting, goldfinch (*C. carduelis*), greenfinch), and many others such as sandmartins (*R. riparia*) in old sand-pits, and swallows (*Hirundo rustica*) in enclosures for foresters' houses. Lack and Venables (8) give useful lists. The ornithologist is concerned with the typical habitat while the forester is interested in any bird which occurs in his woods, so long as it is common enough to influence them. Consequently the definitions given by the two are somewhat different, but the differences are unimportant and can be easily discounted.

As well as 'ground' habitats, birds have a 'height' habitat; Colquhoun and Morley (3) show the heights, or forest levels, at which birds are normally found. They use the following zones: zone 1, upper canopy—above 35 feet; zone 2, tree —15 to 35 feet; zone 3, shrub—4 to 15 feet; zone 4, herb—3 inches to 4 feet; zone 5, ground. The main point which emerges for the forester is that birds, in winter when these counts were undertaken, have a definite height-zone, or story, in which they mainly feed, and that this height is greater in the breeding-season than in winter. Wood-pigeon are the most numerous species found by Colquhoun and Morely in Bagley Wood in zone 1, over 35 feet. They are also sometimes, and perhaps generally, the species most frequently found in the upper few feet of the Tullach Ard strip, 25 feet high, where they can be seen from our windows perching on the tops, and at times breaking them.

Somewhere between a total tree-height of 25 and 50 feet, a plantation changes its bird population from that of a thicket to that of a wood, and this may well be related to zones 2, 3, and 4 above becoming differentiated from zone 1. The matter requires study in woods of different species at different ages and heights, as it will always be easier to bring in birds to their natural habitat than to try to force any change on them, even if the latter is possible at all.

Lack and Venables (8) say 'There is competition for nesting holes among certain species, but in most species competition for nesting sites is entirely absent'. As regards species other than hole-breeders this is often not the case in plantations, where there may be very few sites available in the sparse undergrowth. In such situations the difficulty is overcome on the Continent by planting the edges of rides, roads, &c., with shrubs, which have to be properly pruned to give cups for nest sites. It is useless to plant shrubs and omit the pruning. The writer pointed out (9) that the increase in numbers of nest-boxes occupied in the second and third years after they are put up almost certainly shows that suitable nest holes are in short supply. So in a properly run commercial wood the supply of nesting sites is probably the actual limiting factor to the bird population, and not the food-supply, which, however, must be the ultimate limiting factor, when it comes into play. This difficulty can be overcome if we can find a tree or shrub species really desirable for nesting, and plant them in patches as island sites in plantations of less suitable species.

The great majority of nests in young Scots pine plantations up to 30 years old were in deformed trees, either at a cup, a fork, or a bend where the leader had been lost and side branches were big. In Thuya and Lawson's cypress the very few nests of small birds tend to be at the outer end of branches, except in forked trees. These trees fork, and then the fork grows straight up parallel with the main stem, so the branches from the stem and the forks interlace and form platforms; in some such trees three and four nests have been found at different levels. Deformed and forked trees would be removed in early thinnings, decreasing the number of potential sites.

DATA.

Some 120 counts have been made, and the most important data are given in the Appendix. Plots have been numbered only, as although owners may be quite well aware of the shortcomings of their own woods, in many cases caused by the war, they will not want these broadcast, and a candid record including faults is essential to proper evaluation. Place-names will be deposited with the Imperial Forestry Institute and the Edward Grey Institute of Field Ornithology at Oxford for the use of future workers. Each group of comparable plots has been given a number, each plot within the group a letter.

The object has been to get as high a number of nests as possible to emphasize differences, so island, edge, and end sites have been used where possible. There are also a number of counts in fair-sized woods and a few in forests covering several square miles. Most of the counts were made within 30 miles of Perth, but a very short visit was paid to Bagley Wood, Oxford, and a fortnight was spent at Nairn.

The figure for the number of nests per 10-acre unit corresponding to the count is only approximately correct, as the method was not decided on until most of the counts had been made, and the requisite data have not always been noted.

INTRUSIVE PLOTS AS ISLAND SITES.

Besides the strip at Tullach Ard (Appendix, group 1) already discussed, which is an island site and is really an intrusive plot in 100 acres of young larch and Scots pine plantations, plus a considerable area of fallow and arable land, several other equally remarkable plots have been found although for various reasons they could not be measured exactly. No. 12 is at least 20 acres of 21-year-old Scots pine and some birch with at one end a patch of Norway spruce of the same age and about half an acre of Sitka spruce, 12 years old. The birch contains no nests, the Scots pine near a cottage contains nests at the rate of 200 per 10-acre unit over about an acre only, and the remainder of the pine has 10 nests per unit. The Norway spruce has 2,000, and the Sitka spruce 3,000 per unit, in both cases over a small area only. The Sitka nests cover 2 years only, the Norway spruce 4 or 5. For the actual counts made in this and the following groups, see the Appendix.

In group 28 there are 400 acres, more or less, of 14- to 16-year-old Scots pine. Two sample counts produced 2 nests in 6,000 trees. There is a boggy patch, on the edge of which Sitka spruce has been planted mixed with Scots pine and birch coppice. The undergrowth is very thick and the mixture makes it difficult to

reduce the figure to nests per unit, but a count in this area gave 100 birch saplings, no nests; 250 Scots pine, no nests; 51 Sitka spruce, 22 nests. The approximate figures per unit corresponding to these counts, including the 2 sample counts of 6,000 Scots pine, are Scots pine, 7 nests; birch, 0; Sitka spruce, 1,200. This last may well be higher, as the strip was very narrow and there was no means of exact measurement to hand: it was in any case difficult to say definitely where the Sitka spruce mixture ended.

Group 32 was 17–18 years old. There was about an acre of Sitka spruce, the reason for which was not obvious, with considerable areas of Scots pine and larch round it on the edge of several square miles of plantations. A number of counts in Scots pine and larch in the neighbourhood gave about average results, from 10 to 50 nests per 10-acre unit, mostly about 10. In this group the figure for 500 larch and Scots pine was 0, while 300 Sitka spruce contained 51 nests or 2,040 per unit. The area had been cleaned recently or the figure might have been higher.

These last three Sitka-spruce plots were all island sites surrounded by other species, more or less of the nature suggested below.

In the Culbin sands area about 25,000 trees were examined: 12,000 each of Scots and Corsican pine, about 20 years old, and 1,500 Sitka spruce about 25 to 30 years old. The area is peculiar, with little undergrowth except heather, and that only in places, and with little, if any, water. One nest was found in each of the pines (plus 2 wood-pigeon). The Sitka spruce is a patch of about 2 acres only and lies next to older woods on one side. It contained 13 nests (plus 15 wood-pigeon) in the 1,500 trees, or about 1½ acres examined, which corresponds to 80 per unit as against 1 for each of the two pines. As there were only traces of water in the drains in the Sitka spruce and none anywhere else, these very low figures may be connected with the water-supply. Whatever the reason, the area contains fewer nests than any yet seen, but even so the one patch of Sitka spruce held many more nests than the pines.

CONCLUSIONS.

The order of preference, starting with the most popular species, is:

Sitka spruce.

Norway spruce.

?Cupressus macrocarpa.

Douglas fir, *Chamaecyparis lawsoniana*, *Thuya plicata*, *Abies grandis*, Hemlock (*Tsuga heterophylla*), ? juniper.

Scots pine, Corsican pine, mountain pine.

Larch, yew, all broad-leaved species examined (birch, beech, oak, ash, sycamore, alder, willows, poplar).

Enough data have been collected to make the positions of Sitka and Norway spruce, Scots pine, larch, hemlock, birch, alder, and willows fairly clear. The remainder are thought to be nearly correct, but further counts are wanted to make certain, especially of Douglas fir, of which no really suitable plantations happen to have been found for comparison with Sitka or Norway spruces.

There is little to choose between Scots pine and those species coming below it.

But in the New Forest, in woods containing purely broad-leaved trees except for yews, the goldcrest is common. It nests almost exclusively in conifers, and the few yews found here supply that requirement (Lack and Venables (8)). Spruces would probably serve equally well, or better, but it happens to be yews which are there. *Cupressus macrocarpa* is doubtful; it was only seen in Bagley Wood and there was no time to make proper comparisons.

Preference extends to single trees as in the yews mentioned above, and in the single Norway spruce in 12, *c*, with 6 nests, in the middle of 2,000 Scots pine with 1, but probably such trees should be about the same height and age as the rest of the plantation. It seems to be a plantation that birds like, very irregular growth in the one or two cases seen not being nearly as good as an even canopy.

Gorse and broom are not popular: they had to be cut back over about 5 acres of a Scots pine plantation, 5 years old, and no nests were found. Possibly the absence of song-posts was a contributing cause.

It is not effective to underplant with spruce. The habit of the tree changes when used for this purpose, the foliage becoming thin and the branches close together; the net result is an undesirable site.

There are good reasons for the relative popularity of the various species, and a study of them allows one to forecast how popular a species not previously examined is likely to be. Let us consider disadvantages first. Broad-leaved trees are not in leaf when the first nests are made, so there is no cover, and the branches are not in whorls in unpruned trees, so there is no nest platform. In larch the cover is too light and there is no nest platform. Scots and Corsican pine have the cover too light, and the nest platform is unsuitable (such nests as occur are in deformed trees). *C. lawsoniana* and *T. plicata*, branches alternate and opposite, so there is no nest platform; most nests occur in forked trees. Hemlock provides no nest platform and rarely forks. Douglas fir, the whorls are badly spaced and the branches are too smooth to hold nests easily. *Abies grandis* closely resembles Douglas as a nest site. In *C. macrocarpa* the branches are fastigiate and numerous, giving a good lodgement for nests. Norway spruce has the branches in whorls, but the numerous small twigs make access difficult. Sitka spruce is like Norway, but has fewer small branches. Few nests have been found in plantations where the trees are packed densely in coppice shoots. It is thought that birds like a few square feet of dense growth, but not an acre of it, as moving about becomes difficult.

The factors influencing popularity include: (*a*) a good nest-platform (spruces, Scots pine); (*b*) easy access (Sitka spruce); (*c*) dense overhead cover (absent in Scots pine, larch); (*d*) song-posts (Lack (6, 7)).

Of hedges, only a few have been examined. *Prunus cerasifera* is the most popular at Tullach Ard, with 10 nests in 110 yards over about 5 years. Beech is next with 3 nests in 180 yards. *Lonicera nitida* when grown closely is thought to be too thick. But all these hedges suffer from the proximity of Sitka spruce, which draws the great majority of nests to itself. *Escallonia* is said to be good, but the writer has not seen a hedge of this species. The question may be of importance in nurseries.

Rhododendrons do not seem to be popular.

Birds nesting on the ground have not been taken into consideration and may modify final estimates of general desirability. But the ideal is rather numbers of species of useful birds than numbers of individuals of the same species, and the thicket birds help in this, as the number of species is high.

PRACTICAL APPLICATION.

For the first 20 to 25, and perhaps 40 years, Sitka and Norway spruce plantations do not require help because of their popularity for nesting. *C. macrocarpa* is doubtful, as are *T. plicata*, *C. lawsoniana*, hemlock, *Abies grandis*, and Douglas fir, and until there is more experience to show whether they can look after themselves in the way of nesting-sites, it may be prudent to do what we can for them. Scots pine, Corsican pine, and mountain pine (and probably other pines as well, but this is not certain), larch, and all broad-leaved species which have been examined provide such bad nest sites that it is suggested that small plots of Sitka or Norway spruce should be planted in suitable spots, of the order of one to each 30 to 50 acres of plantation. Plots need not be more than a quarter of an acre, and as long as they are at least 6 to 8 trees wide, are better to be as long as possible, e.g. up the banks of a small stream.

There are other steps which can be taken, such as planting up the edges of roads and rides with shrubs like whitethorn, hornbeam, beech, privet, and Norway spruce, and keeping them properly cut back and pruned for nest sites; but such steps are in the nature of an insurance premium which gives no return, whereas planting up suitable ground with Sitka spruce will give a good yield. Even if it is found that such a plot is most attractive when young, it can be felled and extracted with thinnings as pitprops, and the area replanted. All methods have yet to be tried out in practice on a scale large enough to judge results, financial and otherwise.

Nest-boxes are not suggested, as they have not been seen by the writer in such young plantations. But Lack (6), as noted above, says coal tits use them in young plantations of Scots pine, after about the 8th year, and the earliest date for effective general erection requires investigation. Lack's record shows they have unexpected possibilities.

The writer's thanks are due to the Forestry Commission and their officers, as well as to numerous private owners and their factors who have allowed him to work in their plantations; and to Professor H. M. Steven, and Messrs. W. B. Alexander, of the Edward Grey Institute of Field Ornithology, D. Lack, N. B. Kinnear, H. N. Southern, and others who have helped with advice and suggestions. Having been too busy for 15 years to study either birds or forestry carefully, progress would have been impossible without considerable calls on the time of others, which have always been most generously answered, making any results obtained the product of a co-operative effort.

SUMMARY.

1. In plantations, birds of the thicket type have been found to have strong preferences for nesting in certain tree species.

2. Plots were selected in adjoining plantations of different species, and the nests in them, old and new, counted. Numbers in different pairs give a link-up and enable a list to be made.

3. About 120 plots were examined, and further counts are being made.

4. The normal wood and the woodland bird community and their requirements are discussed.

5. Sitka spruce is the most popular species found, and Norway spruce is next, then *C. macrocarpa*, with Douglas fir, *C. lawsoniana*, *T. plicata*, *Abies grandis*, and hemlock next. Scots and Corsican pine, mountain pine, larch, yew, and those broad-leaved species examined all give poor nesting sites.

6. The reasons are discussed.

7. The suggestion is made that small plots of Sitka and Norway spruce planted in suitable places in plantations of other species giving bad nest sites will increase the number of birds, and examples are given where plots of this nature have been found and contain nests of the order of 40 to 80 per acre per annum.

LITERATURE REFERENCES.

(1) Colquhoun, M. K.: 'Visual and Auditory Conspicuousness in a Woodland Bird Community.' *Proc. Zool. Soc.*, Ser. A, cx, 1941, pp. 129–48.
(2) —— 'Birds of Savernake Forest, Wiltshire.' *J. Animal Ecology*, x, May 1941, pp. 25–84.
(3) —— and Morley, A.: 'Vertical Zonation in Woodland Bird Communities.' *J. Animal Ecology*, xii, Nov. 1943, pp. 75–81.
(4) Elton, C.: 'A Reconnaissance of Woodland Bird Communities in England and Wales.' *J. Animal Ecology*, iv, May 1935, p. 127.
(5) Forestry Commission Bulletin No. 10. *Growth and Yield of Conifers in Great Britain.*
(6) Lack, D: 'Habitat Selection in Birds.' *J. Animal Ecology*, ii, Nov. 1933, pp. 239–62.
(7) —— 'Further Changes in the Breckland Fauna caused by Afforestation.' *J. Animal Ecology*, viii, Nov. 1939, p. 277.
(8) —— and Venables, L. S. V.: 'The Habitat Distribution of British Woodland Birds.' *J. Animal Ecology*, viii, May 1939, pp. 39–71.
(9) Mackenzie, J. M. D.: 'Forest Ornithology. Some Meditations.' *J. R. Scottish Forestry Soc.* lix (in the press).
(10) Nicholson, E. M., and Koch, L.: *Songs of Wild Birds.* Witherby, 1943.
(11) Witherby, Ticehurst, Jourdain, and Tucker: *Handbook of British Birds.* Witherby, 1938–42.

Appendix

Plots Examined

Number	*Species*	*Age (years)*	*Height (feet)*	*Actual count*		*Nests per 1,000 trees*	*Nests per 10 acres*	*Remarks*
				Nests	*Trees*			
1 *a*	Sitka spruce	14	25	246	1,865	140	3,000	Total for 4 years
b	Norway spruce	14	18	16	190	80	2,160	" "
c	Scots pine	14	20	1	290	0·3	90	" "
d	Larch	14	30	1	325	0·3	90	" "
e	Willows, alder	14	30	0	300	0	0	" "
f	Oak, larch	14	8	0	200	0	0	" "
2	Hybrid larch	8	15	0	12,000	0	0	Patchy
3 *a*	Sitka spruce	10	10	5	200	25	500	..
b	Eur. larch	10	10	0	2,000	0	0	..
4 *a*	Sitka spruce	8	10	3	30	100	2,000	Scattered trees

Plots Examined—cont.

Number	Species	Age (years)	Height (feet)	Actual count: Nests	Actual count: Trees	Nests per 1,000 trees	Nests per 10 acres	Remarks
4 *b*	Scots pine	10	12	2	1,500	2	30	..
5	Scots pine	7	8	2	14,000	0	4	..
	The above are the original counts at Tullach Ard.							
9 *a*	Scots pine and larch	40	..	5	500	10	75	All big nests
b	Norway spruce	40	..	22	1,000	22	330	..
c	Scots pine	30	..	0	500	0	0	..
d	Sitka spruce	40	..	15	300	50	450	..
11	Douglas fir	40	..	..	..	..	..	'Few nests'
12 *a*	Scots pine	20	25	5	600	9	200	Cottage
b	Birch	..	50	0	600	0	0	..
c	Scots pine	20	30	1	2,000	0·5	10	..
	Norway spruce	20	30	6	1	..	..	Amongst the pine
d	Norway spruce	20	30	10	100	100	2,000	..
e	Sitka spruce	12	Up to 15	19	150	150	3,000	½-acre plot
6	Thuya, cypress	20	40	10	1,000	10	200	..
	Thuya, cypress	20	40	10	100	100	2,000	Forked trees
7 *a*	Thuya, cypress	20	40	15	1,000	15	275	..
b	Norway spruce	14	20	8	200	40	800	..
8	Hemlock	10	15	0	500	0	0	Mixture
	Norway spruce	10	10	5	100	50	..	Open space
13 *a*	Scots pine	21	25	7	5,000	1	30	..
b	Scots pine	12	12	3	1,500	2	40	..
	Norway spruce	15	15	6	3	..	..	Amongst the pine
15	Larch	19	40	0	300	0	0	..
	Douglas fir	19	40	12	300	40	150	Mixture
16 *a*	Douglas fir	25	60	10	1,000	10	100	..
b	Ash	25	50	0	500	0	0	..
18 *a*	Norway spruce	35	..	2	200	10	100	..
b	Douglas fir	35	..	2	1,000	2	20	..
c	Scots pine	35	..	1	1,000	1	10	..
19 *a*	Larch	30	..	0	300	0	0	..
b	Norway spruce	30	..	6	300	20	180	..
20 *a*	Larch	..	40	1	500	2	20	..
b	Beech	..	40	0	500	0	0	..
21	Yew	..	30	1	200	5	5	Old trees
25 *a*	Scots pine	25	35	4	3,000	1	14	..
b	Norway spruce	25	40	40	500	80	1,000	..
c	Jap. larch	31	70	0	500	0	0	..
27	Juniper	Old	12	8	300	25	..	Scattered
28 *a*	Scots pine	16	20	2	6,000	0·3	5	..
c	Sitka spruce	16	20	22	51	440	1,200	Mixture
	Birch	16	20	0	100	0	0	..
	Scots pine	16	20	0	250	0	0	..
30 *a*	Poplar	10	20	0	200	0	0	..
b	Alder	15	30	0	400	0	0	..
c	Scots pine	22	30	1	5,000	0·2	2	Underthinned
32 *a*	Larch	18	25	0	500	0	0	..
b	Scots pine	18	25	0	500	0	0	..
c	Sitka spruce	18	30	51	300	170	2,040	Cleaned
33 *a*	*Thuya plicata*	16	30	2	300	7	100	..
b	*Abies grandis*	16	40	3	500	6	60	Thinned
	Hemlock	16	35	3	500	6	60	..

Plots Examined—cont.

Number	Species	Age (years)	Height (feet)	Actual count		Nests per 1,000 trees	Nests per 10 acres	Remarks
				Nests	Trees			
33 *d*	Scots pine	16	25	0	300	0	0	..
34 *b*	Scots pine	20	20	1	12,000	0	1	..
c	Corsican pine	20	25	1	12,000	0	1	..
d	Sitka spruce	25	6 to 50	13	1,500	8	80	..
35 *a*	Douglas fir	20	40	0	200	0	0	..
b	Scots pine and larch	20	36	0	400	0	0	..
c	Norway spruce	20	20	5	20	..	..	Small clump
37 *a*	Douglas fir	18	45	5	100	50	200	Mixture
	Sitka spruce	18	45	18	100	180	720	Thinned
b	Douglas fir	18	45	2	800	2	20	Thinned
c	Sitka spruce	18	45	4	20	200	2,000	Small clump
d	Scots pine	18	30	0	1,000	0	0	..
38	*Pinus montana* and hemlock	18	20	0	800	0	0	..
	Sitka spruce	18	20	1	4	..	..	Single trees

NOTES

1 *a–d*. 4×4 feet. Pruned.

2. 6×6 feet. Open, and small in parts.

3, 4, 5. All the above are parts of 100 acres of young plantations.

6, 7. Unpruned. Adjoin extensive policy woods.

8. An open birch wood used as a nurse for hemlock (*Tsuga heterophylla*) and Norway spruce, 50 acres.

9. Overcrowded. Tops of spruce impossible to see into. 500 acres.

12 *a*, *c*, *d*. Want thinning badly. Part of extensive plantations.

12 *e*. Coppice has been allowed to suppress many trees. Cut back last year.

13 *a*. Much too close. Planted 3×3 feet: half the trees dead, rest badly crowded. Area of extensive woods, amongst fields.

13 *b*. Packed tight with coppice shoots. Growth variable.

15. Larch used to beat up Douglas. Good plantation, due for thinning. Nests all medium. 50 acres.

16. 50 acres.

18, 19. Policy woods near by. Extensive plantations.

20, 21. Near Oxford. Small plantations.

25 *b*. Growth very patchy. Where intrusive birch are numerous, nests are scarce. Policy woods near by. 200 acres plantations.

27. Open heath. Juniper scrub.

28. See text.

30 *c*. Badly underthinned. Policy woods close by.

32. See text.

34. Culbin sands. See text. Birds very scarce.

38. A windbreak near a nursery. More nests were expected here.

General. It has been difficult to make all figures correspond exactly after allowing for stocking, treatment, &c., but the differences are as a rule so great that small inaccuracies can be neglected.

Cupressus macrocarpa seen at Oxford, about 15 years old. 6 nests in about 800 trees, as against 6 nests in 300 trees Norway spruce, and 0 in 300 Scots pine. Counts not satisfactory, but given tentatively.

EXPERIENCES IN HARVESTING TIMBER AND THEIR APPLICATION TO SILVICULTURE AND MANAGEMENT

By B. P. URQUHART

1. INTRODUCTION.

IN the next decade the energies of British forestry will be so largely devoted to restocking and creating forests that to refer to problems of harvesting now may seem but to shut the door on a very empty stable. There are, however, many lessons which evolved in the course of exploiting forest produce during the last decade which should interest the forester of to-day. In both State and private forestry there has been a tendency to specialize on silviculture at the expense of utilization, and it is suggested that more attention should be paid to a subject which may, if neglected, minimize the advantages of good silviculture. With a clear picture of the ultimate processes of forestry a forester can mould his silvicultural methods and avoid many costly mistakes. For example, the value of a mature crop depends largely on its accessibility, and this site factor should be assessed almost as accurately as, say, the edaphic factors of a locality. Examples of the relative values of differently situated crops have been given by C. P. Achers (1) and emphasis laid on the fact that costs of haulage alone may so determine stumpage prices that only high-quality timber can stand the charges of transportation. Thus the forester may find that his choice of site, species, and rotation may be dictated to him, within obvious limits, by considerations of harvesting. The successful farmer sites his crops with care to reduce costs of handling, storage, and removal, and perhaps because the short rotations make him ever conscious of these ultimate processes, he may tend to be a better manager of land than the average forester.

2. OBSERVATIONS ON EXPERIENCE DURING THE LAST DECADE.

The following data have been compiled partly from private commercial practice during the 4 years prior to 1939 and from experience in Britain and on the Continent during the war years with a R.E. Forestry Company. There is, of course, a difference between commercial practice and work undertaken by Royal Engineers, in that the latter were primarily concerned with a rapid gross production. Economies which might be entertained in a commercial proposition the army could not afford to risk, piece rates could seldom be applied, and certain operational factors such as mine clearance and constant mobility affected results. However, the men had had valuable training as sappers and the benefit of a variety of mechanical equipment. In the United Kingdom the R.E. Forestry Companies cut several million cubic feet of relatively poor quality oak in the Forest of Dean, while in France, Belgium, Holland, and Germany they cut a wide variety of crops, from poles for log roads to heavy baulks for bridging, and experienced almost every type of problem likely to face the exploiter of timber. Every effort has

been made to draw from experience which was not influenced by exceptional war conditions.

3. TYPES OF EQUIPMENT HANDLED.

(*a*) *Saw-mills.*

Circular saws, both inserted tooth and plate, were used and for about 3 years, in the Forest of Dean, semi-static mills were employed, each producing about 2,000 cubic feet per week, and consisting of one or two rack benches, a power-fed New Zealand type breast bench, and a pendulum docking saw.

As the invasion of Europe approached, new types of highly portable mills evolved. It is not proposed to enter into technical details of mill design, but the following lessons may be drawn from the comparative results of output, man-power, and ease of working, which may be of general application.

Allocation of Standing Timber. It was the practice to license blocks of timber of about 100 acres in extent at a time and to cut the poorer quality of oak first. This was no doubt expedient since the timber was being converted by heavy-gauge circular saws with between $\frac{1}{4}$ inch to $\frac{5}{16}$th inch kerf into sleepers and second-grade products. The rate of gross production demanded often resulted in insufficiently accurate cutting to produce high-grade timber such as solebars, even if suitable trees had been made available. The oak averaged between 15 to 18 cu. ft. Hop. per tree and yielded between 500 to a rare maximum of 1,500 cu. ft. Hop. per acre. This low density of stocking resulted in rapid clearance and constant moving of extraction plant, and two mills sited together soon depleted all adjacent stocks. Again, it often occurred that insufficient timber was allocated to provide a full year's work for all the mills. In consequence one area (Crabtree Plantation), an easily accessible one, was cut in the summer and another (Green-bottom) was allocated in the winter when its extraction damaged rides, roads, and equipment.

The lessons were clear. If semi-static mills were to be used, sufficient timber to provide winter and summer fellings should be obtained in a single allocation. Where there was a low density of volume per acre it was seldom worth building roads and some agreement ought to have been reached with the owner of woods to consider a road-building programme several months before harvesting. This programme might be arranged jointly between the owner and harvester, preventing unnecessary damage and benefiting both parties. Temporary roads built of slab wood, if carefully laid, may last several years, but are an undesirable legacy to the forester.

In 1943 several types of portable mills were constructed. There was a tendency for these to develop into semi-static units simply because roofing, offices, shelters, stack yards, and mill roads became too elaborate and sufficient transport was available to feed them with timber. There was, however, evidence that they could produce only 25 per cent. less timber than the big mills, with a saving of labour and capital which would have allowed at least 50 per cent. drop in production and still compare favourably with the static mills. It was not until 1944 and the invasion of the Continent that the portable mills came to be fully tested.

By eliminating long belt-drives and using 'V' belts and chain drives, the mills became compact and the main centre section only 19 feet long. To this were attached two detachable 'wings' of the rack bench. Tarpaulins to cover approximately 20 feet by 24 feet were found to be adequate to protect men working in all weathers. (See Plate VI, fig. 2.) C. P. Ackers (1) quotes that the typical Scotch portable mill takes 10 days' production to move to a new site. The 'chain-drive' portables could start cutting within 4 hours of arrival on site, but, including all detailed construction which continued while the mill was cutting, a whole day might be necessary to obtain good working conditions, using only the saw-mill gang to erect it. These mills worked in severe and diverse conditions. They worked and moved in trucks from Normandy to Germany and no serious stoppages or breakdowns occurred in 12 months. Their portability reduced the volume of cubic feet necessary to establish them in each block of woodland and indeed suggests the ideal type for the small scattered woods of Britain.

Power. Steam, paraffin, and diesel engines were used as power units at various times. Of steam engines the 12–16 h.p. (nominal), fitted with dutch ovens and consuming sawdust and waste, were the most economical to run, but required more skill to maintain than the diesels. A thorough test of the water to be used was found to be necessary as serious stoppages occurred due to unsuitable mineral deposits in untested water. Steam provided the best type of power in that the variable loads of sawing seem to be accepted more smoothly by steam than by I.C. and C.I. engines. Of the diesel engines, the vertical high-speed types were preferred since they took little time and material to instal, whereas the large single-cylinder horizontal engines required concrete foundations and at once rendered a mill static. Tractor power, run on paraffin, proved unsuitable for continuous saw-milling owing to constant vibration and slow response to governors.

(*b*) *Haulage Plant.*

More attention is paid, in this paper, to equipment directly concerned with the extraction of timber than to saw-mills, since it more closely affects management and silviculture. In assessing the merits of different types of machinery it is important to remember how much the skill of the operator may influence the results. The handling of timber requires long experience to be efficient. There is a heavy demand on physical strength and therefore great need to eliminate waste of effort. The skill of Canadian lumbermen, among whom we often worked, illustrated the high levels of efficiency which can be reached by long and specialized experience in logging. In training British personnel to operate new types of equipment, the axeman and the estate employee generally adapted themselves more readily to mechanized logging than men from mechanical trades or State forests.

Tractors. Both wheeled and track-laying or crawler tractors were employed. Wheeled types can do useful work, but are primarily designed for agriculture and proved unable to withstand prolonged haulage in winter. As soon as crawler tractors became available, wheeled types were confined to minor work on good

roads and in mill yards. Those fitted with winches were used in the forest to load timber on to trucks and trailers.

Over a period of 5 years crawler-tractors varying in size from 95 h.p. to 20 h.p. and including Caterpillar, Allis Chalmers, Cletrac, David Brown, and International models extracted several million cubic feet of timber from poles of pitwood size to logs 3 or 4 feet in diameter. The efficiency of these machines has been judged on gross output in relation to fuel consumption and reliability and no data on capital costs have been considered.

Crawlers. At first crawlers were employed to drag timber along the ground from stump to road and to haul pole wagons or trailers along rides unfit for trucks or wheeled tractors. Later log arches were attached (see Plate V, fig. 2) to the crawlers to lift the butts of logs from the ground and drag only the tapering ends along the soil surface. Largely developed in the west coast lumber trade of the United States, crawler tractors are now recognized as the ideal vehicle to travel over the rough surfaces of woodlands.

Before the introduction of the log arch, tractors dragged logs sometimes from forest to mill over distances of more than a mile. Where this occurred, the constant use of one approach caused deep channels to form which in winter turned into watercourses. Mud and gravel became embedded in the bark of logs and damaged saws, and each tractor's load accumulated mud on the ramps of the saw-mills. It soon became evident that ground skidding of logs should be confined to short distances and the number of journeys over the same ground strictly limited. The figures given in Tables I and II illustrate that without an arch a tractor assembling and skidding its own loads on short hauls may move as much or more timber than one tractor and a log arch, provided the ground is hard and dry. This is due to the fact that the tractor and arch are more difficult to manœuvre amongst scattered logs than the tractor alone. The efficient use of a log arch demands a small subsidiary tractor or horses to assemble logs into loads. The arch ought not to assemble and should be confined to work on tracks 9–10 feet wide free of stumps and sharp stones. On gradients it should travel at right angles to contour lines and provided the tractor and arch can climb a slope without its load it can descend it loaded. C. R. Townsend (4) suggests that the maximum gradient that a Caterpillar D8 can negotiate may be 76 per cent. or 37 degrees. In the Forest of Dean tractors and arches operated successfully on gradients of 42 per cent., though in wet weather the tractor occasionally failed to climb owing to slipping tracks. In Table II it is shown that the tractor with arch improves its performance and becomes increasingly more efficient than a tractor skidding logs along the ground, as the length of haul increases. Unfortunately no data were recorded for the consumption of fuel in Table II.

In Table I the economy of fuel is demonstrated when a log arch is used to reduce the load's friction and drag. The figures give a general indication of the relative efficiency of different methods and represent averages on 20 days' work in each case. The personal element involved, differences of terrain over which each series of loads were hauled, and the differing loads tend to make the results too variable to allow statistical analysis. It is interesting to note, however, that

similar conclusions were arrived at by C. R. Townsend (4), who states that in the Southern States costings proved that friction-reducing devices such as the log arch were found to be essential for all but the shortest of skidding distances.

It is difficult to emphasize the importance of planning to haul over steep and broken country during summer months and to avoid heavy muddy roads at all times. The Caterpillar Company give the following figures to illustrate the resistance of different road surfaces (Table III).

TABLE I. (*Summer Conditions*) *1942*

One-way distance of haul in feet	*Type of equipment*	*Average daily fuel consumption (gallons)*	*Cubic feet* (H) *hauled per day (8 hours)**
1,500	International TD9 with winch	8·3	980
1,500	TD9 with winch and Hyster log arch	7·1	870
1,500	TD9 and Hyster log arch	7	1,800
	TD6 assembling logs for arch	6	

TABLE II. (*Winter Conditions*) *1943*

One-way distance of haul in feet	*Type of equipment*	*Average daily fuel consumption (gallons)*	*Cubic feet* (H) *hauled per day (8 hours)**
1,500	TD9 and log arch TD6 assembling	..	1,200
1,500	TD9 TD6 assembling	..	620
3,000	TD9 with arch TD6 assembling	..	1,100

* Logs hauled were oak 18–30 feet in length × 11–16 inches m.q.g.

TABLE III. *Resistance of crawler tracks in pounds per ton of gross load*

Road surface	*Pounds*
Earth roads, dry	85
„ „ muddy, uneven	150
„ „ very muddy, sticky	225

Maintenance. Crawler tractors cost four or five times as much as wheeled tractors and require constant care. Skilled maintenance is considered more important than driving skill, though a driver with general experience in handling timber will haul more per day than one with mechanical experience only. For example, on the International model TD9 there are 20 points to be greased twice daily, 7 daily, and a further 8 weekly. In addition, periodic changes of filters, air cleaners, &c., are necessary. After two years' experience we drew up a detailed set of

instructions for the use of tractors employed on hauling timber, specifying in a log book the lubrication, methods of driving, and special parts which required constant attention. Owing to accidents which damaged radiators when tractors worked on steep slopes or among heavy branches, improvised bumpers were fitted in addition to the maker's guards. From figures recorded in tractors' log books, it was found that International TD9's required a weekly average of 5 hours for maintenance when new and up to 20 hours per week when 2 or more years old. C. R. Townsend (4) states that in Canada it is usual after a crawler has worked 4,000 hours to exchange it for a new one.

In order to obtain the maximum of working hours we arranged for tractors to be serviced while drivers rested, but it was found preferable to leave this task to the driver and hooker. The latter could then also learn to operate the tractor, and this system reduced repairs, probably on account of the greater interest each operator took in his machine. The tyres of log arches required attention so that small cuts could be checked and air pressures maintained. Since tyres are the most costly parts of the arch they merit constant inspection.

Trucks and Trailers. The tractor and arch soon became standard equipment to feed portable mills in the forest. But the static mills erected in England demanded the use of wheeled transport, since only in one instance was there sufficient timber adjacent to the mill to supply it without 4–6 miles' haulage by road. Owing to the low density of timber per acre it was seldom economical to build roads and therefore the vehicles had to travel on rough forest rides as well as on metalled roads. A variety of transport was employed, from converted army trucks to specialized articulated timber vehicles. Since capital costs were not known, once again efficiency was judged on production in relation to fuel and man-power. The most successful results were obtained from short wheel-based trucks pulling trailers. One truck could keep three 5–10-ton trailers constantly moving on a shuttle system. On short hauls (under 1–2 miles) only 2 trailers were required.

Converted Austin W.D. vehicles with 6 by 4 wheel-drive gave long and reliable service as traction units to haul trailers and could themselves carry 3-ton loads of timber cut to 10–12 feet lengths. Their fuel (petrol) consumption, however, averaged 6–8 miles per gallon.

Heavy diesel-engined gun-tractor (F.W.D.) vehicles pulled 10-ton trailers as opposed to the 3–4-ton trailers of the petrol-driven vehicles. They possessed an auxiliary front-wheel drive, reduction gears, a powerful winch, and a relatively low fuel consumption (diesel) averaging 10–12 m.p.g. These vehicles proved ideal for heavy timber, and perhaps their only disadvantage was a broad wheel base which was often too wide for normal forest rides.

Articulated vehicles did not prove satisfactory on the whole, since having 2 wheel-drive they could only operate on hard dry roads. One Austin 6 by 4 with its 3 trailers could deliver in a day 2½ times as much timber to a mill as an articulated Austin 4 by 2 timber wagon. This ratio increased where the vehicles were obliged to use muddy forest roads. Canadians often used semi-trailers, and the specialized self-loading types used by the French suggest that there is room for development in the design of trucks for timber work. Until such designs mature

it is probably advisable to use a standard short wheel-based truck capable of pulling a variety of trailers and to modify the trailers or pole wagons to suit the range of forest products to be transported.

Horses. The great output of timber which machinery will produce over long continuous periods tends to make one regard the horse in timber work as an anachronism. Experience indicates, however, that the horse can still fulfil certain demands. For example, the assembling of logs into loads for tractors and arches to remove may be more economically performed by horses than by tractors. It was found that horses could work in confined areas where branches, tops, and logs interfered with a tractor's mobility. In the Ardennes 2 horses and a teamster assembled sufficient logs to enable constant hauls by a tractor and arch over distances from ¼ mile to 1 mile. Generally, it has been noticed that farm horses are not suited to timber haulage and that specially trained ones only should be used. For one reason, the strain of timber haulage may ruin a horse for agricultural work, and, secondly, trained animals reduce the time and effort required to direct them. In Holland, however, some 20,000 pine logs required for constructing corduroy were extracted form young plantations on farm carts. Confined and stump-ridden ground prevented the use of arches; similarly tractors could ground-skid only limited loads. One horse and cart was found to average two-thirds of the production of a TD9 tractor. The hauls did not exceed 200 yards and logs averaged 12 feet by 6 inches mean diameter.

C. R. Townsend (4) quotes that operators working in the Southern States limited hauls of timber by horses to a maximum of 400 feet.

Loading. The costs of loading and unloading may play a main part in the transport of timber, and the efficiency of haulage plant depends on the organization and skill of loading. It has been shown (3) that the economics of harvesting timber may be influenced by the use of costly machinery which must work at its maximum designed capacity to be effective. During experience gained in the last decade the following items seemed to govern the speed and efficiency of loading: (i) length and diameter of logs; (ii) straightness of logs; (iii) equipment in relation to local conditions; (iv) labour in relation to equipment and methods of loading.

Conifers as a whole were found to be much easier to load than hardwoods, due primarily to their straight even boles. Though heavy logs, given suitable equipment, could be loaded more rapidly per unit of weight than light ones, this advantage disappeared if the heavier logs were crooked. It was found important to insist on careful trimming, for snags left on the logs hindered movement and piling of loads.

R. E. Worthington (5) illustrates the way in which costs of loading increase in inverse ratio to the diameter of the logs in experiments undertaken in the United States. For example, the time taken per 100 cu. ft. to load pine logs 12 inches in diameter averaged 0·20 hour, 24-inch diameter 0·08 hour, and 36-inch diameter 0·05 hour. These times applied to one method of power loading on to trucks in the Southern States.

In clear felling crops of timber a variety of sizes of log accumulate and it was often found difficult to separate these before loading. This work should be done

by the tractor which assembles the logs so that graded or classified loads are brought to the loading-point. It was often found necessary to construct separate loading-points for the smaller timber so that different methods and plant could be employed. This ideal is not often easy to attain and, therefore, the forester should note that where a system of clear felling reigns, crops should be so treated that the final one yields the minimum diversity of size classes.

TABLE IV. *Loading Times*

Mid-quarter girth classes of timber	*Types of equipment loaded*	*Method of loading*	*Average time in minutes per ton loaded*
Oak 12–14 inches straight selected	3/5-ton pole wagons articulated	Parbuckling from ground-level	6
Oak 12–14 inches unselected	3/5-ton pole wagons articulated	Parbuckling from ground-level	8·5
Oak 12–14 inches unselected	3/5-ton pole wagons articulated	Parbuckling off raised loading banks	5·5
Oak 14–18 inches unselected	10-ton trailers	Jib crane from ground-level	4·3
Oak 12–14 inches unselected	Hyster log arch 3/4-ton max. load	Log arches and TD9 crawler with winch and S.W.R.	2·1

Ton = 24 cu. ft. hoppus.
Loading by Fordson fitted with rear winch and steel wire rope.
Weather and ground: Summer, but occasionally wet and muddy conditions.

In Table IV figures based on 24 days' loading indicate the average differences of loading times as applied to conditions in the Forest of Dean in the summer of 1942. The loading of a log arch clearly takes less time and energy than any other method, partly due to the fact that only the butts of the logs are lifted. Of the other methods employed the most satisfactory in areas where the density of stocking of the crop exceeded 1,200 cu. ft. per acre was that of loading off an elevated bank. Logs 20–30 feet long were laid and supported by upright poles so that a ramp projected out from the bank, and the overall height exceeded the truck or trailer to be loaded by 12–18 inches. Logs were drawn on to this ramp by tractor-arches and then skidded by winches on to the vehicle.

Various types of jib were tried and proved successful after initial difficulties due to lack of experience. To lift heavy logs to a height of 6–10 feet considerable skill is required to attach slings or dogs to the centre of balance and prevent the log swinging. Though the figures shown in Table IV indicate a low average time, on several occasions (not recorded) serious stoppages occurred.

Woodmen in Britain are less accustomed to methods which involve overhead lifts and improvised cranes than to simple parbuckling. The latter method requires a minimum of equipment and at first was universally employed. The low density of stocking in many of the areas felled in the Forest of Dean necessitated

constant moving of loading-points. It was, therefore, found uneconomical to construct loading banks. Logs were classified into approximately even-sized loads and trailers or pole wagons drawn to positions opposite each load and the logs parbuckled up on to the trailers. Straight logs averaging 10–14 inches in diameter could be loaded in groups of 3 or 4 at a time. The frequent change of loading site prevented accumulations of mud and damage to roads and reduced the distances of tractor hauls.

Parbuckling is a slow method, though liable to few stoppages, and should be confined to logs which do not exceed a ton in weight. Heavy logs place a strain on skids and trailers during the initial raising of the log. Judicious use of pulley blocks may reduce the strain and in confined spaces the direction of pull by the winch may be altered.

It was found that trailers were easier to load than trucks, in that there was no danger of damaging the cab and misplaced logs were accessible from either end of the chassis.

Unloading required less skill but as much organization, for its speed depends much on co-operation by saw-mill gangs. Most delays in unloading occurred when vehicles were kept waiting at saw-mill ramps by the men cross-cutting logs for the mill, or because of lack of storage space in the mill yard.

The mill manager will always prefer a load to be deposited directly on to the ramp feeding the break-down bench, and if logs are already sprawled across the ramp, will keep the loaded wagon waiting until the ramp is cleared rather than allow it to unload into a storage dump where logs will require additional handling. The most rapid unloading was undoubtedly from the log arch, averaging 1 minute per ton unloaded, and any increase in this figure was usually due to waiting. In the Ardennes, where speed of extracting timber controlled the success of the whole project, saw-mill ramps 35–50 feet long were constructed and detailed orders given to keep a 10-foot wide passage clear on the ramp at all times. Other limiting factors in unloading proved to be in certain designs of the stakes which retain loads on wagons. Many standard designs proved unsatisfactory, and the most successful evolved from the adaption of a Canadian method, using a hinged stake and chains. (See Plate VI, fig. 1.) Once again the advantage of trailers over trucks may be observed in that a loaded trailer could be left by a ramp while the traction unit returned to the forest with an empty. For the unloading of heavy logs from trucks and trailers light friction winches driven off the saw-mill's power-plant proved very efficient and allowed rapid unloading.

Decauville Track. Narrow-gauge rails and bogies were employed to distribute sawn timber in the stack yards of mills, and for removing sawdust. For hauling logs over marshy or agricultural land its use may be justified, but it would appear to require high densities of stocking. In the Ardennes, Belgian contractors were observed to use it extensively in roadless marshy areas to extract spruce.

(*c*) *Tools.*

Generally the types of axes and saws common to British practice produced the best results. Trees were felled close to the ground leaving shorter stumps than

usual in continental forests. It may be asked whether the pride which an axeman takes in felling close to the ground may always be an advantage. Often the lower 6 inches of a tree is buttressed and full of 'inbark' and the extensive laying in by the axe to reduce a sharp taper may not be justified. However, it is probably a fault on the right side and usually delighted the continental forester.

Power saws of the chain type proved unreliable at first, but once the operators had overcome initial prejudices and been fully trained to maintain them they were universally employed on saw-mill ramps to cross cut logs. For felling they were not found to be so suitable. When trees leaned slightly in the direction in which they were to be felled the power saw was much quicker, but it was found difficult to use wedges. In Canada it has been found that power chain saws cannot yet compete economically with hand tool methods (4) for felling.

It is more usual in British practice to use chains for dragging and loading, but gradually a more extensive use of steel wire rope was developed. Handling, splicing, and a thorough knowledge of S.W.R. would appear to be a rare and useful asset to a woodman. Canadian types of 'choker' were extensively employed on the slings to attach logs to tractors and proved more rapid to handle than the usual British method of looped slings and C hooks.

4. THE PLANNING OF A PROJECT TO HARVEST TIMBER.

As already mentioned, the costs of extracting and hauling timber may easily be the major cost to the consumer and, therefore, the preliminary study necessary to any plan prior to its execution is of vital importance. To a trained and methodical mind much of this preliminary work may be automatic, but it was found expedient to follow a definite routine of investigation even if it entailed a few redundant items. The sequence was as follows:

(i) *Preliminary Reconnaissance.*

First the availability of necessary equipment and trained personnel for reconnaissance had to be checked. From maps and orders a picture of the operation was formed and a tentative plan prepared, including a map on which were sketched ideally placed mills and extraction routes.

(ii) *Field Reconnaissance.*

Usually it was necessary to take sample plots or strip surveys to determine the distribution of size classes. Often the total volume was presented in the preliminary reconnaissance, but this figure had sometimes to be checked as well.

Next all roads and rides had to be traversed and examined and drainage in relation to topography and climate assessed.

Whenever possible a local representative was asked to attend, and except in Germany was invariably available to give information on local resources and the micro-climate.

The layout of the mills, the road systems, loading-points, and a camp site were then marked on to the sketch-map and a system of priorities of work detailed.

Felling Plans. Systems and direction of felling varied with each operation, but a standard plan was adopted from which it was seldom necessary to deviate.

Brushwood and tops of felled trees were laid in heaps and logs were drawn towards rides through the standing timber. Whenever possible, felling should start a week or two ahead of the arrival of the saw-mills, but in practice this seldom occurred and tractors worked close behind the axemen. As one felling strip was being cleared the fellers were working at the beginning of a new strip. The width of felling strips depended on the shape of the area and distances of haulage but were seldom more than two rows wide. In this way felling did not impede the work of the tractors.

5. APPLICATION TO BRITISH FORESTRY.

Saw-mills. In the next decade the country's resources may not extend to extensive road building, and the necessity to utilize the product of small scattered woodlands and inferior growth will be greater than ever.

In order to avoid transporting waste, which may include 50 per cent. of the log, it has long been the practice in Scotland to convert timber in the forest. The average Scottish mill requires at least 50,000–60,000 cu. ft. in one area to warrant its erection, but it is suggested the new type of portable described may reduce the economic unit to 10,000–15,000 cu. ft. However frequently the portable mill is moved, the necessity for a sustained supply of timber remains. For example, the capital cost of the type of mill described and its attendant haulage plant demands a gross production of some 40,000 cu. ft. per annum. Few individual owners of woodlands will intend to cut such quantities, and therefore some form of co-operation appears to be the only solution to maintaining economic forestry.

Portable mills should not cut logs over 24 inches in diameter and such timber would be transported to static mills, in addition to the smaller sizes of special trees such as ash of 'sports' quality. The problems of disposing of such timber have never been serious.

In static mills the usual trend to-day is for the band saw to take the place of circular saws, which should be limited to breaking down inferior logs. The practice adopted during the war of squaring logs in the forest on portable mills and sending the squared baulks to be sawn in band mills may in certain conditions prove economic. In this way the costs of haulage may be reduced, the baulks stand the cost of carriage to good markets, and the waste be utilized locally.

From what has been said it is evident that intimate knowledge of markets and detailed costings will decide the policy to be adopted, but the fact remains that some cohesion of supplies from scattered units will be necessary.

Haulage Plant. The crawler tractor with winch has proved itself to be one of the ideal forms of haulage within a forest. Its tracks distribute the load and allow it to work on soft ground and with a log arch reduces the necessity for metalled roads. Angle-dozing equipment may be fitted, and it may also be used for ploughing and other cultural work.

The truck may also form an essential part of harvesting equipment, since one will be required to move portable mills and tractors to various sites and transport labour. The ideal type would appear to be a diesel-engined vehicle on a short wheel-base with an auxiliary front-wheel drive capable of hauling a variety of

trailers. C. R. Townsend (3) records an estimated life of 400,000 ton miles for F.W.D. trailer-type trucks as against 50,000 miles for ordinary 3–5-ton lorries, and a lower cost per mile to operate. As for saw-mills, efficient plant entails a high capital cost and therefore constant work. Once more the conclusions point towards a co-operative basis on which to lay a specific policy.

Diverse local conditions make it as dangerous to generalize about forestry as about agriculture, but the continued existence of scattered blocks of woodland suggest the following principles to promote the economic harvesting of timber.

(*a*) Woodlands within a determined area should be associated into an economic group. The size, both in area and volume, of each group would depend on topography, distribution of age classes, and policy, revealed in simple working plans.

(*b*) Plant, labour, and technical supervision would be obtained on the scale demanded by the survey in (*a*). Silvicultural requirements would be estimated as well in order to ensure versatile plant and labour.

(*c*) Ideal equipment and skilled labour may prove to be unobtainable at first, and in the survey indicated in (*a*) all existing facilities should be considered. The most economic static mill in a group may be owned by the timber trade or by a forest owner. Similarly a portable mill may be owned and operated by either the trade or a group of owners. Haulage equipment other than that intimately associated with the portable mill may be more economically operated by a haulage contractor. Provided the group of forest owners obtain the necessary cohesion amongst themselves and study all the facts, the common policy considered essential to economic forestry will evolve.

Thinnings. In outlining the policy indicated above, the volume of thinnings from both State and privately owned forests must be estimated. For some time the harvesting of timber may in many areas be largely confined to the products of thinning. The low density of volume per acre, inaccessibility due to inadequate roads and rides, and extraction through standing trees together combine to make the vital task of thinning unattractive and consequently one of the more neglected operations in British forestry. At present many instances have been observed of poles from early thinnings being dragged by hand to rides. This may be unavoidable during the first thinning of certain species such as pine, but such work usually destroys the margin of profit on a product already difficult to utilize economically.

On steep slopes overhead cables and chutes have been used successfully in Britain, but the problem of feeding these lines of transport remains. It is suggested that research on the use of power-operated cables (i.e. light portable winches) and special types of horses would yield positive results. To facilitate the use of such equipment the forester should consider, not only the usual straight planting lines, but intervals of widely spaced rows down which poles may be extracted. Already research has been applied to wide planting and pruning, and it is suggested that wide planting, from 6 by 6 feet up to 10 by 10 feet every 50 feet, would greatly aid problems of extraction during early thinnings.

Ponies and light horses can be trained to haul poles on difficult rocky slopes, and successful results have been, for example, obtained in the fells of the Lake District. It is suggested that agricultural holdings adjacent to forests should be

encouraged to breed and train such animals, for the transport of horses to and from a site of work should be reduced to a minimum.

Management and Silviculture. Dr. C. A. Schenk (4) writes in reference to Canada, 'Forestry is a problem less of silviculture than of permanent transport facilities'. Though this principle may be truer of Canada and its vast trackless forests, it may also have a direct bearing upon silvicultural systems of the future in Britain. Dr. Schenk continues: 'With good lines of transport always ready, clean cutting becomes folly. And who would neglect the chance of a second growth near a permanent good road?'

The shelterwood systems and all those involving natural regeneration may develop more widely in Britain. In the majority of continental forests where shelterwood systems predominate there are good roads throughout the forests, and it is interesting to note such equipment as crawler tractors are rarely tolerated by the grower. Even wheeled tractors are uncommon. Specialized self-loading trucks and such types as the French Latil rank high among efficient vehicles for the carriage of timber, but horses are chiefly used to drag logs to the roadside.

To extract timber the following hauls usually succeed each other: (*a*) from stump to ride or track; (*b*) from track to road; (*c*) from road to market or sawmill. The more facilities there are for (*b*) and (*c*) the shorter the hauls in operation (*a*). It is in the first stage (*a*) that difficulties arise, for the dragging of timber along the ground and between standing trees can damage a crop. It is suggested that the State forests of the Continent are perhaps conservative and by insisting too much on primitive haulage by horses the value of timber is lowered. Crawler tractors do damage to advance growth and disturb the soil. However, where adequate seed trees remain they may even stimulate regeneration and more than replace the damage. Examples of dense natural regeneration of ash and sycamore have been observed at Cirencester, concentrated on ground churned up by crawlers, and to a lesser extent Silver fir in Aberdeenshire. The provision of tracks 10 feet wide suitable to tractors and log arches at 1,000-foot intervals will reduce ground skidding (*a*) to 400 to 500 feet. Where tractors are to be excluded, then tracks may have to be increased and spaced at intervals of 600 feet or less to make horse haulage more economical.

In British woods, where fencing is necessary and selective felling intended, then rides and tracks must converge on the minimum of exits.

Thus in planning silvicultural systems the forester must visualize the sequence of operations throughout a rotation. In the creative stage it would appear that the specialist in silviculture requires the opinions of the specialist in utilization, and that on road systems may depend much of the success of silviculture.

The invention of bulldozers and scrapers has reduced the cost of roadmaking, and the former were used extensively in the operations already described (see Plate V, fig. 1). Such equipment will probably become a standard accessory to the crawler tractors employed in every forest or group of woodlands. It is not proposed to enter into details of road construction, but the roads encountered in most of the forests exploited during the war appear to have suffered from long

neglect of drainage. An earth-bound road will stand up to heavy tractor traffic if well drained, and to wheeled traffic in dry periods. Roads shut in by dense shade and ill drained will never be a success. In the laying out of new roads careful thought should be given to the types of equipment likely to travel on them so that curves, gradients, and widths will not handicap the harvester of the future. For short temporary hauls the harvester of timber will improvise temporary methods such as roads of brushwood, corduroy, or slabwood, therefore it is perhaps advisable for the forester to concentrate on the surfaces of his main system, leaving unplanted tracks at frequent intervals.

In deciding on the species to be planted as well as on the system of silviculture the forester should consider problems of harvesting. Mixtures of species should be considered in terms of felling, for though light-crowned trees such as larch do not damage undercrops (1), the spreading crowns of some hardwoods, especially seed trees, require careful and therefore more expensive felling. Heavy crowns are also a feature of the selection system and may involve increased costs. In the Forest of Dean the following figures were recorded and indicate the comparative production of felling heavy crowned oak and those of better form. Figures were based on 52 days' work by trained axe-men.

	Average size of tree in cu. ft. Hop.	*Total cu. ft. cut per man day (8 hours)*
1. *Heavy-crowned trees* 600 cu. ft. per acre	18·76	52 cu. ft. Hop.
2. *Light-crowned trees* 1,500 cu. ft. per acre	24·8	73 „ „ „
3. *Heavy-crowned trees* (no cording) 600 cu. ft. per acre	19·2	120 „ „ „

In examples 1 and 2 felling included trimming and cross-cutting all branchwood into 4–5 feet lengths and stacking in cords.

In example 3, oak were felled in the same area as example 1, but were felled and trimmed only; no cording of branchwood was included. As in previously quoted figures, allowances must be made for the personal element and the fact that in no case were trees felled on piece rates. The light-crowned oak in example 2 possessing a larger average volume may also have increased the higher production.

The size to which timber is to be grown must be considered not only in relation to silviculture and market requirements. Examples of plantations of Douglas fir in a deep valley are known where trees over a certain diameter proved uneconomical to extract. The rotation thus was limited where it might have been extended on a different site.

Records. Information of the kind which is demanded by all text-books on forestry seldom seems in fact to exist in a working plan or else the data does not appear in the form suited to the demands both of management and utilization. It is suggested that almost all the harvester requires to know about a crop can be incorporated in a map. Such a map might be termed the 'Harvest Map', but need

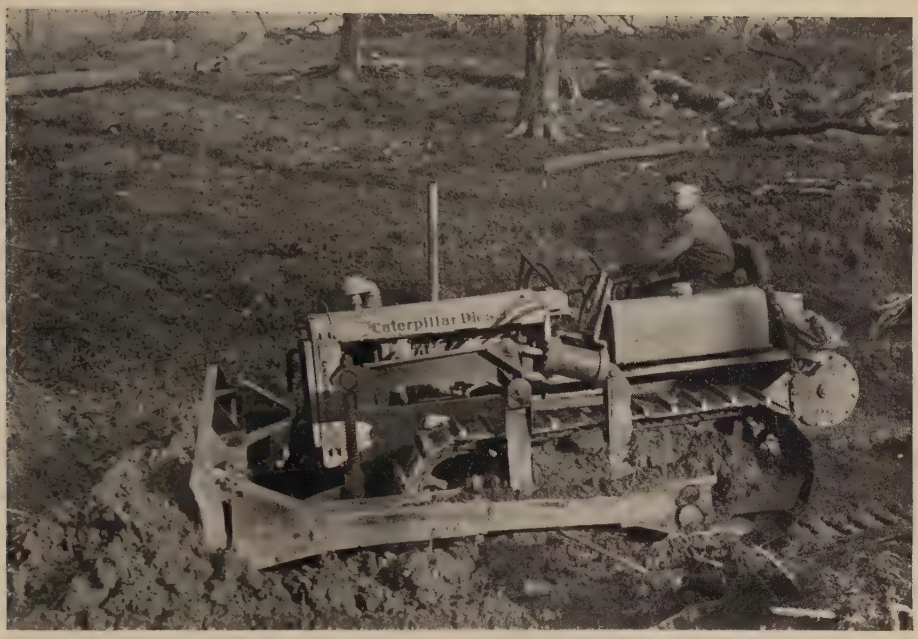


FIG. 1. Caterpillar D4 with bulldozer, clearing and grading a log-arch track (Forest of Dean)

FIG. 2. International T.D.9 with Hyster log arch, approaching ramp (Holland)

PLATE V

Fig. 1. Chain and wood securing-pins which allowed rapid unloading

Fig. 2. Portable sawmill, showing ramp, breakdown saw, and tarpaulin roof. Power—26 H.P. Diesel. Saws—4 ft. inserted tooth, 3 ft. inserted tooth, both power fed. Detachable locking saw

PLATE VI

not necessarily be so specialized. On it should be shown amongst others the following features:

(1) A classified road system. Summer roads and tracks, metalled roads, differing widths, gradients, and surfaces, clearly contrasted.

(2) Sub-compartment boundaries where differing distributions of size classes and species are marked, to facilitate rapid calculation of probable yields of both thinnings and mature volumes by area. It is assumed that species, age, and volumes are normally indicated for each compartment.

(3) Probable mill sites, loading banks, and camp sites. From the planting stage to maturity of a crop heavy loads come and go and a bank to raise loads to a level of 4 or 5 feet will save man-power. These items may seem a little fantastic to the forester about to plant a bare expanse, but such facts should be recognized and recorded so that they may be considered in relation to other demands and be available to each successive forest manager to incorporate into his period of management.

Perhaps the advantages of aerial survey have not been fully appreciated in Britain; for the layout of roads and rides on plantable areas aerial photographs would assist the forester in a difficult task.

5. SUMMARY.

The article describes a variety of methods of harvesting timber during the war in which many types of mechanical plant comparatively new to British practice have been used. The merits and demerits of plant and methods have been discussed and an attempt made to assess how far they may be applied to future operations in British woodlands.

Finally, the relationship between the practice of harvesting timber crops and the principles of silviculture and management have been considered, and the attention of foresters drawn to the necessity of understanding, during the coming period of reconstruction, problems of utilization which affect silviculture.

6. LITERATURE REFERENCES.

(1) Ackers, C. P.: *Practical British Forestry.* 1938.
(2) Hiley, W. E.: *The Economics of Forestry.*
(3) Townsend, C. R.: *The Motor Truck in Wood Operations.* 1937.
(4) ——— *Mechanised Logging.* Canadian Pulp and Paper Association. 1938.
(5) Worthington, R. E.: *Enquiry into Costs of Tractor Logging in Southern Pine.* Southern Forest Experimental Station, U.S.A.

SOCIETY'S AND OTHER NEWS

FINANCES

The audited Abstracts of Accounts for year 1944 were adopted by the Council on 28 February 1945. The credit balances were: General Fund, Capital £423. 2*s*. 4*d*., Revenue £487. 6*s*. 11½*d*.; Medal Fund, £23. 9*s*. 2*d*.; and Excursion Fund, £23. 3*s*. 4*d*. As before, the bulk of the balances was on loan to the Treasury, either in Government loans or through Edinburgh Savings Bank.

MEMBERSHIP

During 1944 the membership increased from 159 to 172; and there has been a good accession of new members in 1945, bringing the total up to 192 at the end of September. We regret to have to report that one Fellow, Lieut. John Cyril Briggs, B.Sc. (For.) (University of Wales), was killed in action in north-west Europe early in 1945.

OFFICE-BEARERS

At the Council Meeting on 28 February 1945 Mr. W. A. Robertson, who had recently accepted a full-time appointment with the Colonial Office, resigned from the Presidency, and Mr. W. H. Guillebaud, Chief Research Officer, Forestry Commission, who had been Vice-President, was elected President. Mr. O. J. Sangar, Assistant Commissioner, Forestry Commission, was elected Vice-President, and Mr. W. L. Taylor, Forestry Commissioner, who ceased to be immediate Past-President, was elected a Councillor in place of Mr. Sangar.

NEXT ANNUAL GENERAL MEETING

The Council have decided that, if practicable, an Annual General Meeting be held in the second half of September or first half of October 1946, preferably in a city from which an excursion can be arranged.

THE LATE MARTYN RALPH KNIGHT JERRAM, M.C.

We regret to record the death of Mr. Martyn R. K. Jerram, M.C., Lecturer in Forest Management at the University College of North Wales, Bangor, which occurred on 9 May 1945 at the age of 61.

Jerram joined the Indian Forest Service from Cooper's Hill in November 1905, and served in the Punjab throughout his career in India. He was an exceptionally efficient forest officer and would doubtless have risen high in the Service, but, owing to ill health. he retired in 1922. During the period 1915–19 he served in the 2nd Gurkha Rifles in Mesopotamia (where he won his Military Cross) and in France.

He was appointed Lecturer on the staff of the Department of Forestry at Bangor in 1932 and threw himself whole-heartedly into the work of the department. He was a most successful teacher, especially in the practical courses in the field and in the continental tours with the students. He produced two books during his period at Bangor. The first was a small text-book on Forest Management, for use as a basis for his lectures. The second was a more important one—*Elementary Forest Mensuration*, in which he approached the subject from the point of view of the practical forest officer rather than that of the statistical theorist. On his return to Bangor from war service in 1944 he commenced to

revise and expand this work, but, unfortunately, he died before he had progressed far enough to enable others to carry on the project on the basis of his notes.

Jerram's patriotism and sense of duty led him to join the forces in 1940 at the age of 56. He served first as a private and later as an officer in a coastal defence unit of The Buffs. Later he retired from the Army and joined the Royal Navy. His long experience as a yachtsman in the English Channel made him particularly fitted for service in the small ships and his last appointment was as Lieutenant in the R.N.V.R. in command of a mine-sweeper during operations in Italy. When the war in the Mediterranean was over, he felt he could return, at the age of 60, to civilian life, and he resumed his work in Bangor, which he actively carried on until a week or so before his death.

Jerram was unmarried. He was a keen mountaineer and spent much of his leisure time in climbing in the Welsh mountains. He had a circle of friends, not only on the staff of the college but outside, who will miss him sadly. His high-minded devotion to duty, kindly and generous spirit, and thoughtfulness for others endeared him to all. It is some satisfaction that VE day, which marked the successful end of the struggle to which he had contributed his full share, should have occurred just before his death.

If Jerram had lived he would undoubtedly have contributed considerably to post-war forestry education and his influence on the young men who would have passed through his hands would have been of the highest value for the future standard of the Forest Services at home and in the Colonies.

T. T.

REVIEWS

Co-operation in Forestry. By I. Kissin. Technical Communication No. 2, Imperial Forestry Bureau, Oxford.

Forestry Credit. By I. Kissin. Technical Communication No. 3, Imperial Forestry Bureau, Oxford.

Reviews by Professor Henry Hamilton

THESE two papers by Dr. Kissin are specially valuable for those interested in the economics of forestry. The first is the larger and brings together much useful information on the extent of co-operative forestry both at home and abroad. Though producers' co-operation has a long history, it is really only since the War of 1914–18 that it has shown marked development. The reason for this is not far to seek. Economic uncertainties of the inter-war period compelled united action, and where more necessary than in forestry where problems are so much influenced by long-term considerations?

Dr. Kissin distinguishes two main types: first, societies mainly of forest owners, found chiefly in Britain, Denmark, and Finland; and, second, workers' societies engaged wholly or partly in forest work, found mainly in south-eastern Europe and in Russia. The former provides expert assistance in woodland management and also engages in marketing the produce of members. Sometimes marketing is on an agency basis, in which case the society has little need of capital, the risks being borne by the owner; in other cases the society buys production outright, and here capital is required and risks may be considerable.

Britain was late in developing forestry co-operation, the first society being founded in 1911 by a group of landowners in Argyll. The two other British societies were not founded until the mid-thirties. They derived their origin from the movement towards organized marketing and the desire to promote better utilization of home-grown timber. These societies, however, do not appear to have fulfilled the high hopes of their founders, for, as Dr. Kissin points out, members sold only a minute proportion of their produce through them. This disappointing result may be due to sturdy independence or more likely to the fact that in a rising market owners find little difficulty in making their own marketing arrangements. Yet because of efficient market organization and ability to allocate orders to the most suitable estates, co-operative societies promote stability and confer great benefits on customers. Dr. Kissin gives a more promising review of co-operation in Denmark and Finland. In the latter, forest co-operation made great strides in the ten years before the war.

Societies of Forest Workers are found mainly in south-eastern Europe and in the U.S.S.R. Since the foundation of the Soviet régime there has been great extension of forestry co-operation, including forest exploitation, mechanical conversion of wood (the largest activity), and the chemical utilization of wood. The movement is integrated and in recent years has built up an extensive retail trade. Provision of education, libraries, canteens, and playing-fields are also undertaken by the Russian societies.

Forest Credit is a very illuminating account of an intricate subject. Economists will derive much profit from Dr. Kissin's careful study of the special economic problems of forestry. There are, of course, points of similarity with agricultural credit, but it is the important differences on which the author concentrates. The paper deals first with the

functions of forest credit, problems arising from loans on security of forest credit; and, secondly, with the experience of Germany, Norway, Denmark, and the U.S.A. In the case of Britain and the Dominions the author has found little information, because credit problems of forestry have not yet received adequate attention.

Forestry on Private Lands in the United States. By Clarence F. Korstian. Duke University School of Forestry, Bulletin 8, Durham, North Carolina.

Review by James Macdonald

At a time like this, when foresters in Great Britain are conscious of the problems with which private forestry in this country is faced, it is of great value to have a picture of private forestry in the United States drawn by one of the leading authorities on that side of the Atlantic. Dean Korstian's work, which was undertaken at the request of the National Lumber Manufacturers' Association, does not cover all the States in the Union but deals in detail with eight of them, typical of the principal timber-producing areas. They are New York for the north-east, Michigan and Wisconsin for the Lake States, Virginia, Alabama, and Arkansas for the Southern States, and Oregon and Washington for the Pacific North-West.

Lumber and pulp companies are very large owners of forest land in the United States, and they are by far the most important of her private owners. Their concern over the situation is easily understood. Until about the year 1874, the North-eastern States were the principal producers of lumber; then the Lake States secured the lead and kept it until 1900, when they lost it to the Southern States whose predominance lasted until 1926. About that time the Western States became, as they still remain, the greatest producers. What this means is that there are now no important timber areas left which have not been worked over. It is no longer possible to break in a big way into virgin country. The great commercial concerns are being driven back, therefore, on good forestry and organization on the basis of sustained yield.

Most of the forest land is privately owned in the sense that it is not possessed by the States or by the Federal Government, but a holding of 600,000 acres—and Korstian mentions two such cases in Arkansas alone—is not quite the same as private forestry as we know it here. On the other hand, more than three-quarters of the privately owned forest in New York State is in ownership of less than 5,000 acres each; the 13,000,000 acres of private forest in Virginia are in the hands of about 300,000 different owners and in the Lake States—Michigan, Wisconsin, and Minnesota—15,000,000 acres or 29 per cent. of the commercial forest area are on farms. Such wide differences in the size of individual holdings must add enormously to the complexity of the situation.

The problem, to put it crudely, is how to bring the existing forest areas under management to the condition in which they will be able to meet the needs of industry by a sustained yield. This problem does not seem to be insoluble. Although its area is considerable, the proportion of really derelict forest land is low, much lower than in England; the area of understocked forest, on the other hand, is high, but the author indicates that this can be put right in a relatively short time by the practice of an adequate silviculture. And although overcutting is going on, and going on seriously in some States, it is not universal, and at its worst is trifling in comparison with what the woodlands of Great Britain have suffered during the last 6 years. It is generally agreed in the United States that the first step towards management is the control of forest fires. Vast damage has been done by fires which have broken out accidentally or have escaped from control, damage which in

many cases has led to the complete destruction of large tracts of mature and immature timber and which on occasion has been followed by attacks of insect pests. Fires have also led in certain districts to the replacement of valuable species by others of less importance. Many States have in force laws regulating fire protection, but measures of protection vary in efficiency from State to State. In New York they are described as adequate, in the Southern States as quite insufficient. In the North-Western States of Oregon and Washington there is an interesting and effective system of protection in which the Federal and State Governments join with the private owners who provide the greatest part of the necessary funds. How seriously the problem is regarded there is shown by the expenditure of about 1,500,000 dollars in 1941 on fire protection alone in the State of Washington.

Timber operators, many of whom are now pursuing an enlightened policy, can do much to maintain the continuity of the forest by careful management of their fellings, and an interesting illustration is given of the 'staggered settings' of Douglas fir in Washington. Elsewhere the prevailing tendency on the more progressive estates is to use a kind of selection method—one can scarcely call it a system—which in its crudest form means cutting to a diameter limit. Considerable improvement appears to have been effected by this method in certain localities, but it is possibly the most open to abuse of all forms of management and its widespread adoption would seem to require as a sequel some form of public or professional control of silvicultural practice.

The author states that 'public control of forest cutting practice on private lands in the United States now appears inevitable' and most of the people with whom he talked seemed to have held the same view. About all are agreed that such control should be exercised by the State authorities and not by the Federal Government in Washington. Already 22 out of 48 States in the Union have passed or have drafted legislation regulating in one way or another cutting practices on privately owned forest land, and the author in an appendix prints a draft of a model bill for State control of cutting on private forest lands. This makes interesting reading and indeed the whole of this American legislation might well repay a study by some foresters in this country.

Korstian recommends increased co-operation between public authorities and private owners, and, incidentally, between the various Federal forestry authorities themselves. He also recommends the setting up of 'co-operative sustained yield management units' which have been authorized by the Sustained Yield Act, passed into law by Congress in 1944. It often happens that in one district forest lands are owned by the Federal Government, by the States, and by private owners, and to quote Korstian, 'In many localities with intermingled landownership, the permanence of timber-growing and the wood-using industries could be assured through a pooling of public and private forest lands under single co-operative management'. This Act authorizes the appropriate ministers to make co-operative agreements with landowners who are willing to join in the scheme. The development of forest management under this Act in the United States should be followed in Great Britain with the closest attention.

Conditions in the United States are quite different from those in this country, but the problems of the American forester have something in common with our problems here. This book, therefore, can be recommended to British foresters who will find it a useful, and in some places an illuminating, commentary on private forestry.

(1) *Trees and Toadstools*. By M. C. Rayner. Faber and Faber, London. 1945. Price 6*s*.

(2) 'Taxonomic-Ecologic Studies of the Boletaceae in Northern Idaho and Adjacent Washington.' By A. W. Slipp and W. H. Snell. *Lloydia*, vol. vii, pp. 1–66, March 1944.

Review by H. M. Steven

DR. RAYNER'S new book (1) is designed not for the forester but for the general reader who is curious about the ways of Nature. It is, nevertheless, warmly recommended to foresters for two reasons: the drama takes place mainly in woodland scenes, and there are few readers who will not increase their knowledge of such by reading this book; and secondly, the book is written in a discursive way that often stimulates interest.

The book is short, some 60 pages, and there are 18 plates. The introductory chapter deals with the contrasting ways of life of trees and toadstools. In it medieval knowledge and modern science are pleasantly mixed: we go abruptly from the evidence from Spenser's *Shepheard's Calendar* that toads sit on toadstools to a discussion of the reproductive mechanism of the Basidiomycetes. The title of Chapter II, 'The Fungi of Woodlands', is scarcely apt, because the author roams over a much wider field. Some space is given to the lesser known activities of *Armillaria mellea*, such as its remarkable association with the Japanese orchid *Gastrodia elata*, which only produces flowering shoots when its tuber is attacked by rhizomorphs of the Honey Agaric. In the next two chapters the author comes to grips with the question of tree mycorrhizae. It is a readable and well-illustrated general account of this subject which the author has made her own. It is not a summary of all recent work, but that would probably have been less interesting to the general reader than this individualistic treatment.

The publishers are to be congratulated on an attractive format.

One of the most important families of the Basidiomycetes from the point of view of mycorrhizal associations is the Boletaceae. The second paper (2) deals with members of this family in the forest communities of Northern Idaho and adjacent Washington. The boletes found in the Thuya–Tsuga climax association and in its seral communities are described in detail. The principal reason for bringing this paper to the notice of readers is that it presents evidence to show that just as the tree dominants in the various seral and climax communities differ, so do the bolete species. For example, on new burns dominated by *Epilobium* no boletes have been recorded. In the *Pinus contorta* var. *latifolia* seral community, the principal bolete is *Suillus* (*Boletus*) *granulatus*. The *Larix occidentalis* and *Pinus monticola* communities have similar species, *Suillus* (*Boletus*) *elegans* and *Boletinus clavipes* being two of the most common species. In the Thuya–Tsuga climax association, the most common species are *Xerocornus* (*Boletus*) *Zelleri* and *Boletus mirabilis*.

Some of these species are well-known formers of mycorrhizae, but much remains to be known about this and their ecological relationships. Nevertheless, it appears almost certain that these variations in distribution arise from their mycorrhizal status. Further, this evidence emphasizes anew that these fungi are sensitive to differences in environment.

NOTICES

Behold Our Green Mansions. A Book about American Forests. By Richard H. D. Boerker. University of North Carolina Press and Oxford University Press, 1945. Price 24*s*.

THIS book is an important and attractive addition to the books that deal in a general way with American forests and forestry. Many have only to see it to want to read it, and foresters could, with advantage, recommend it for purchase by their local public libraries, because much of it applies not only to America.

The wide sweep of its subject-matter can best be shown by mentioning the chapter titles: What is conservation?; forest resources of the United States; recreation for the people; relation of forests to wild life; forests and the water-supply; holding the soil; forests and flood control; lumber and its by-products; forests as a livestock range; forestry and agriculture; fire, the destroyer; insect enemies; tree diseases and forest sanitation; leadership of the Federal Government; progress of the States in forest restoration; forestry problems in the south; community forests; economic factors in private forests.

Most of the chapters give an interesting and up-to-date bird's eye view of their subjects. Even the best informed professional forester will learn something new, and the general reader will gain a clear picture of the importance and interest of most aspects of forests and forestry.

The crown of the book is its well-chosen and beautiful photographic illustrations. There are 96 plates, principally U.S. Forest Service photographs, illustrating the subjects discussed. Many, particularly amongst those illustrating the recreational and wild life aspects of forests, would rank high in any collection of pictorial subjects; for example, 'The view of Mt. Baker, Washington State', and 'Beaver in the Adirondack Mountains'. Others show features of ecological and silvicultural interest not noted in the legends, such as the invasion of Douglas fir in a *Pinus contorta* stand, and *Tsuga* in a stand of Douglas fir. There are in addition many maps and diagrams, but these are not so striking as in some recent American publications.

Erosion in the Punjab, Its Causes and Cure. By Sir Harold Glover. The Civil and Military Gazette, Ltd., Lahore, 1944. Price 23*s*.

PERHAPS nowhere in the world is the problem of erosion more important than in the Punjab. Its level plain has now been covered by canals all taking off from rivers rising in the Himalayas to the north. If, therefore, erosion cannot be checked in the hill country, the whole economy of the province will collapse as did the ancient civilizations of Mesopotamia and for the same reason.

This book deserves the attention of all interested in this important subject. It is a workmanlike and beautifully illustrated account, first of the basic facts, secondly of the important work already done, and thirdly the results already achieved, many both striking and encouraging. Forest officers will be interested to note that in 1939 the Punjab Government decided to entrust the restoration of the eroded lands to the Forest Department and created a special Soil Conservation Circle.

The book is divided into two parts. Part I deals with the subject for the province as a whole, and Part II for each district in turn.

The importance of this book for the general reader is the emphasis it places on the economic causes of erosion, and the social and economic measures taken to combat it. The fundamental cause is a population in the hill country greater than the land can support. The result is overfelling and overgrazing which in turn leads to erosion and further impoverishment, not only where the soil is torn from the slopes, but in the distant plain. The measures necessary for cure are simple and well known, the difficulty is to get them adopted, and this is where this publication has something really valuable to say. The first point of interest is the propaganda measures to overcome the suspicions of grazers and cultivators. These included illustrated lectures and travelling models of eroded and improved land. After an uphill fight this made it possible to close eroded forest areas to grazing. Economically, this is only possible if the people obtain profit from forest produce for their own use or for sale. For example, closure is often followed by rank growth of grass. Its beneficent effect in checking erosion does not appear to be reduced by permission to cut it for use and sale. An interesting and successful example of the social and economic approach is the Kangra Village Forest Societies. In 1938 the Government decided to form village forests out of reserves, protected forests, common grazing lands, and village waste, and promised to hand over the whole revenues, provided the people undertook to manage the whole village estate in such a manner as to prevent erosion, and according to a working plan drawn up and sanctioned by Government in consultation with the people. Progress has been remarkable, and 51 village forest co-operative societies, covering 65,000 acres, have been formed in this district. The limiting factor is now trained staff for drawing up plans, &c. The description of this scheme, and the Society's rules and model by-laws will be of wide interest.

It is hoped that these few observations indicate the importance of this volume.

Mining Timber. By S. E. Wilson. Reprinted from *Wood*, and published by The Lumberbook Company, Clevedon, Somerset. Price 2*s.* (2*s.* 2*d.* post free).

THIS is an excellent general, and well-illustrated, account of this important subject. It is dealt with in three parts: mining timber in use, supply and demand, and home supplies and forestry. All foresters should read this account.

Swelling Stresses in Gels. By W. W. Barklas. Forest Products Research Special Report No. 6. H.M. Stationery Office, 1945. Price 1*s.*

IT is well known that large forces may be exerted during the constrained swelling of hygroscopic gel materials such as wood, and at a time when such materials, in the form of composite wood products or synthetic plastics derived from natural fibres, are finding their way into exact engineering design, the phenomenon of swelling stresses is beginning to assume considerable practical importance.

The present report is the result of work done during recent years by the Department of Scientific and Industrial Research at the Forest Products Research Laboratory on the calculation of swelling stresses and elastic constants of wood and wood products, but as the subject is one likely to have wide applications to other materials, the treatment has been kept as generalized as possible. The report is intended to show the possibilities and practical importance of a quantitative treatment of swelling stresses, and is likely to interest the physicist and engineer as well as the physical chemist. It contains a detailed explanation of the implications of the swelling stress equation in terms of the mechanical behaviour of the gel under changing humidity. The hygroscopic properties assumed for the idealized

gel are defined and the mathematical treatment based on these properties is exact. The degree to which the properties of real gels depart from the ideal is discussed, and the points at which this necessitates the use of approximate mathematical solutions is stressed.

The report first explains the nature of swelling stresses and the reasons for their occurrence. It shows why the stresses set up by gels, though essentially similar to the osmotic pressures exerted by true solutions, are of a more complex type owing to the fact that gels possess rigidity and can, therefore, sustain shear stresses, whereas true solutions can exert hydrostatic stresses only. Following this explanatory introduction, the exact thermodynamic equation is derived, showing the change in vapour pressure of a rigid elastic gel when subjected to a given system of external stresses, and allowances are made for any change in moisture content which may result. It is then shown how the elastic constants of the swelling material are involved in this equation, and methods are described for determining the elastic constants from measurements of swelling and sorption without the need for measuring the pressures involved.

The report goes on to show how, in certain cases, one may calculate the elastic constants of the solid constituent of a porous gel such as wood and the internal stresses set up when natural wood is allowed to swell. By way of illustration, a description is given of the methods employed in making approximate calculations of these quantities from standard data on the hygroscopic properties of wood.

Few gels are truly elastic in the sense of showing reproducible and reversible behaviour under repeated loading, and a chapter is devoted to this subject, explaining how the plasticity of gels can be invoked to explain the fact that the vapour pressure exerted by a gel at any given moisture content is higher when equilibrium is reached by adsorption from a lower moisture content than by desorption from a higher moisture content. This hysteresis in sorption results from the plastic hysteresis in the internal stresses set up by the swelling and shrinking of the gel.

Forests and Forestry in Great Britain. By W. L. Taylor. Crosby Lockwood & Son, Ltd., 1945. Price 12*s.* 6*d.*

THIS important book was received too late to be reviewed, and this brief notice is intended only to bring it to the notice of readers.

Here at last is a book about British forestry which the professional forester can recommend without reservations to the general reader and which he himself can read with profit. It is readable, balanced, and salted with wisdom; the illustrations are attractive. It should be on the bookshelves of all interested in forestry, and it is hoped that such will recommend it to those who are not.

FORESTRY COMMISSION PUBLICATIONS

Many Forestry Commission publications are still available for sale or free distribution, although others are temporarily out of print. A complete list of those at present obtainable is given below.

The following may be obtained on application to the Secretary, Forestry Commission, Camp House, Promenade, Bristol, 8.

Applications relating *only* to those publications marked * should be addressed to H.M. Stationery Office, York House, Kingsway, London, W.C. 2, or to any Bookseller.

Bulletins	*Price* s.	d.	*Postage* d.
4. The Douglas Fir Chermes	2	0	1½
*11. Nursery Investigations	3	6	3
*12. Forest Gardens	2	6	3
*13. Studies on Tree Roots	2	0	2
*14. Forestry Practice	1	6	2
15. Studies of Scottish Moorlands in relation to Tree Growth	2	6	2½
16. Studies on the Pine Shoot Moth	1	0	1½
Reports, &c.			
British Empire Forestry Conference, 1920	7	6	4½
Report on Census of Production of Home-grown Timber, 1930		3	1
Interim Report of the Inter-departmental Home-grown Timber Committee, 1933		4	1
Report of the National Forest Park Committee, 1935		6	1
Report of the National Forest Park Committee (Forest of Dean), 1938		6	1
Report on the Demand for Timber for Box and Packing Case Manufacture in Great Britain		9	1½
Report on the Demand for Timber in Coal-mining in England and Wales	1	3	2
*Report on the Demand for Timber in Wood-turning in Great Britain	1	3	1½
*Report on the Demand for Timber in Shipbuilding and in Docks and Harbours	1	3	2
Argyll National Forest Parks Guide		6	1½
*Report of the National Forest Park Committee (Glentrool), 1943		9	1½
*Report by the Commissioners on Post-War Forest Policy (8.6.43)	2	0	2
*Supplementary Report on Post-War Forest Policy (27.1.44)		2	1
Or the two Reports	2	2	2
Report of the National Forest Park Committee (Hardknott)		4	1

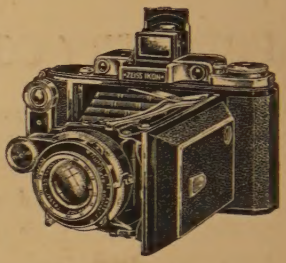
*Annual Reports of the Forestry Commissioners. Year ended 30 September: 1921, 1922, 1924, each 1*s.*; 1925, 9*d.*; 1926, 1*s.*; 1927, 1928, each 9*d.*; 1929, 1*s.* 3*d.*; 1930, 1931, 1932, 1933, each 9*d.*; 1935, 1*s.*; 1936, 9*d.*; 1937, 1*s.* (Postage 1*d.*)

Leaflets (free of charge)

1. Pine Weevils. 3. The Pine Shoot Beetle (*Myelophilus piniperda*). 8. Douglas Fir Seed Fly (*Megastigmus spermotrophus*). 9. Forest Fires. 10. The Oak-leaf Roller Moth (*Tortrix viridana*). 11. Larch-shoot Moths. 12. Income Tax and Death Duties on Woodlands. 15. The Felted Beech Coccus (*Cryptococcus fagi*). 16. Larch Canker (*Dasyscypha calycina*). 19. Elm Disease (*Graphium ulmi*). 20. Watermark Disease of the Cricket Bat Willow. 21. Leaf Cast of Larch (*Meria laricis*). 22. Pruning in Young Plantations. Special Leaflets: No. 1. Pit Props. Insect Attack consequent on War-time Fellings.

CAMERAS

Complete Stocks of all the latest Cameras by the leading Manufacturers



We specialize in the correct PROCESSING OF FILMS *and the making of* PRINTS, ENLARGEMENTS, *and* LANTERN SLIDES

J. B. WATSON

3 Frederick St. EDINBURGH **13 and 15 Shandwick Pl.**

ELWES & HENRY'S TREES

7 VOLUMES

URGENTLY WANTED

Please offer to

ROBERT D. STEEDMAN

17 SAVILLE ROW, NEWCASTLE-UPON-TYNE, 1

Also any other good books on Forestry and Botany

Printed in Great Britain at the University Press, Oxford, by John Johnson, Printer to the University